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Chemistry laboratory behaviors affecting scientific understanding and attitude development.

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CHEMISTRY LABORATORY BEHAVIORS AFFECTING

SCIENTIFIC UNDERSTANDING AND

ATTITUDE DEVELOPMENT

A Dissertation Presented

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CHAPTER I

INTRODUCTION

Historical Overview of Chemistry in America

Colonists to 1872

When the colonists disembarked on the North American continent, chemistry was beginning to emerge from the mysteries of alchemy. Manufacturing and medicine had contributed to this emergence by adding descriptive information to the existing body of knowledge. The impetus for the addition of chemistry to the educational curriculum was provided by the medical profession's establishment of medical schools for the training of prospective doctors. The subject matter of chemistry in such institutions, if taught at all, was generally included in a course entitled natural philosophy or natural history and emphasized the practical aspects of chemical education.[1] Faculty who were appointed to teach the subject were generally appointed as professors of chemistry and materia medica.[2]

In 1769, prior to the outbreak of the American Revolution, Benjamin Rush was appointed to the first chair in chemistry at the medical school

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[1]Lyman Newell, "Chemical Education in America from the Earliest Days to 1820," Journal of Chemical Education, IX (April, 1932), p. 677.

[2]Rufus Phillips Williams, "The Planting of Chemistry in America," School Science, II (April, 1902), p. 75.

of the College of Philadelphia.[3] However, it was not until the arrival of Priestly in America in 1793 that academic interest in chemistry increased.[4] This period of heightened interest produced men such as Hare, Silliman, and Cooke, who developed the subject of chemistry as a course suitable for the college curriculum.

Robert Hare, an excellent and inventive teacher, was appointed to the faculty at the Medical School of the University of Pennsylvania in 1818 where he devised the apparatus used in his experiments and demonstration work. His ability to perform demonstrations was widely known and respected, and at the same time he possessed one of the best demonstration halls in existance.[5] "...the originality of his experiments and the variety and extent of the apparatus employed all combined to make Hare one of the greatest of America's chemistry teachers."[6]

In 1802, Benjamin Silliman accepted an appointment to teach undergraduate chemistry at Yale University. The president of Yale convinced Silliman, although he had never studied the subject of chemistry, to accept the position of professor of chemistry and natural history at Yale. Since he had been appointed to this position with the understanding that he would seek training in chemistry, he attended the University of

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[3]Paul J. Fay, "The History of Chemistry Teaching in American High Schools," Journal of Chemical Education, VIII (August, 1931), p. 1536.

[4]Sidney Rosen, "The Rise of High-School Chemistry in America (To 1920)," Journal of Chemical Education, XXXIII (December, 1956), p. 627.

[5]C.A. Browne, "The History of Chemical Education in America Between the Years 1820 and 1870," Journal of Chemical Education, IX (April, 1932), p. 706.

[6]Williams, "Planting of Chemistry," p. 80.

Pennsylvania.[7] While studying at the university he met Robert Hare, who, along with Silliman, conducted experiments in the basement laboratory of their boarding house. Silliman, respecting Hare's ability as an experimenter, learned many investigative techniques from him. Later, Benjamin Silliman returned to Yale to assume his teaching duties and eventually established the American Journal of Science.[8] He was also renowned as a popularizer of chemistry, since he traveled around the country delivering dynamic lecture-demonstrations before numerous lyceums.[9]

Josiah Cooke, who attended one of Silliman's lectures, was appointed professor of chemistry at Harvard in 1850 at the age of twenty-three. Chemistry at that time consisted of a few lectures with no laboratory work. To Cooke is given the credit for introducing medical students, in 1853, to a qualitative analysis course with laboratory. However, prior to that time, he established a laboratory in the basement below his lecture hall for his private use where students were not allowed to work unless given special permission.[10] Two of Cooke's students, Francis H. Storer and Charles W. Eliot, who subsequently became important figures in the historical development of chemistry, were both given permission to use Cooke's laboratory.[11] Eliot appreciated this opportunity and considered it an important phase of

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[7]Newell, "Chemical Education in America from the Earliest Days," p. 687.

[8]Ibid., pp. 688-9.

[9]Williams, "Planting of Chemistry," p. 80.

[10]Ibid., p. 142.

[11]Tenney L. Davis, "Eliot and Storer-Pioneers in the Teaching of Laboratory Chemistry," Journal of Chemical Education, VI (May, 1929), p. 870.

his science training. "I was the first student who ever had the chance to work in the laboratory in Harvard College, and that was entirely due to the personal friendship of Prof. J.P. Cook who fitted up a laboratory in the basement of University Hall, entirely at his own expense."[12] "This whole subject of laboratory teaching is one that interested me very much when I was young. I profited by the only chance there was in Harvard College when I was a student here sixteen years of age, and I have never forgotten my obligations."[13]

Both Eliot and Storer were appointed faculty members of the Massachusetts Institute of Technology in 1865. They planned the laboratories for the new institute and initiated the chemistry curriculum.[14] One of the first laboratory manuals published in the United States, entitled A Manual of Inorganic Chemistry Arranged to Facilitate the Experimental Demonstration of the Facts and Principles of the Science, was jointly authored by Eliot and Storer.[15] That students did not make proper use of this manual was propounded by Eliot:

> The difficulty we encountered was this-that almost every person into whose hands we put those proof sheets and asked to use them in the actual performance of experiments, wanted to regard the experiment as a means of verifying the statements in the manual, not for the purpose of seeing for themselves; having read what the phenomenon was, they were willing to try and produce this phenomenon as a means of verification... Now we have a perfect flood of experimental manuals in all the sciences, intended for use in elementary instruction, and I think that I discern

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[12]Charles Eliot, "Laboratory Teaching," School Science and Mathematics, VI (November, 1906), p. 703.

[13]Ibid., p. 707.

[14]Davis, "Eliot and Storer-Pioneers," pp. 875-6.

[15]Ibid., p. 868.

> in all of them, through all of them, that this same difficulty occurs, that the teacher must always struggle against that tendancy of youth, the main part of whose time is given to memory studies, to regard the book, the statements of the manual, as an authority which he accepts but is willing to verify by inspection of the results of experiment.[16]

The distinction that Eliot earned as president of Harvard University and the eminence that Storer received as an agricultural chemist could not have been foreseen at that time.[17]

In addition to being president of Harvard, Eliot was also interested in public education, as exemplified by his chairmanship of the influential Committee of Ten appointed by the National Educational Association on July 9, 1892.[18] This committee's influence on our public educational system is still felt as a result of its recommendations such as the proposal for a uniform curriculum for all students.

Secondary Level

The eighteenth century was one in which education was largely classical in nature,[19] and the Latin Grammar schools showed no evidence that science was part of the curriculum.[20] Their main function was the

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[16]Eliot, "Laboratory Teaching," p. 705.

[17]Davis, "Eliot and Storer-Pioneers," p. 879.

[18]Theodore R. Sizer, Secondary Schools at the Turn of the Century, Report of the Committee of Ten, National Educational Association (New Haven: Yale University Press, 1964), p. 209.

[19]Fay, "History of Chemistry in American High Schools," p. 1533.

[20]John H. Woodburn and Ellsworth S. Obourn, Teaching the Pursuit of Science (New York: The Macmillan Company, 1965), p. 169.

teaching of Latin and Greek.[21] The academies, which began to appear in the middle of the eighteenth century, rejected the undue emphasis on the classics. At the same time, as a utilitarian and practical outlook enveloped the nation, the academies offered chemistry as a subject in an attempt to achieve practical objectives.[22] While only seven academies included chemistry as a subject in the curriculum in 1820, by 1840 the number had jumped to thirty-five.[23]

The scientific laboratory was not included in the secondary schools at this time. Experiments, if conducted at all, were in the form of demonstrations, and quality apparatus, good textbooks, and competent teachers were difficult to find.[24] The inadequacies of the textbooks, as well as the teaching methods, are illustrated by Fay in the following quotation:

> The method of teaching used throughout this period was predominantly that of assigning material in the textbooks and of hearing the pupils orally repeat the same material. Many of the early textbooks were written in the form of catechisms. And until after the middle of the century chemistry textbooks contained numerous questions at the bottom of the pages or in the appendices. These questions were usually memoriter and were often trivial. No independent thinking on the part of the pupil was stimulated.[25]

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[21] Alexander S. Rippa, <u>Education in a Free Society, An American History</u> (New York: David McKay Company, Inc., 1967), p. 40.

[22] Fay, "History of Chemistry in American High Schools," p. 1538.

[23] Newell, "Chemical Education in America from Earliest Days," p. 678.

[24] Ibid., p. 679.

[25] Fay, "History of Chemistry in American High Schools," p. 1546.

Fay also indicated that criticism was leveled against high school chemistry textbooks, since subject matter was treated superficially by authors who wrote in more than one field of science.[26]

From 1872 to 1910

The enrollment in secondary school chemistry began to increase considerably after Harvard University began accepting chemistry for admission purposes in 1876.[27] At the same time, by outlining the topics to be studied in the high school chemistry course, Harvard exerted a tremendous influence on secondary school chemistry. In conjunction with this, and compounding the influence of the colleges, college professors, because of their knowledge of subject matter, wrote textbooks and manuals of improved quality for use in the high school. However, this trend rendered the textbooks less interesting since they emphasized theoretical rather than practical aspects of the subject.[28]

Furthermore, in a period when college professors were aware of the need for the science laboratory, few educational institutions included it in the chemistry curriculum. The necessity for this new educational tool was accentuated by the return of students from German universities. As a result, the inclusion of laboratory facilities was intensified in both colleges and secondary schools.

Liebig, who taught chemistry in Germany, is credited with the

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[26]Ibid.

[27]Rosen, "Rise of High-School Chemistry," p. 316.

[28]Fay, "History of Chemistry in American High Schools," p. 1547.

use of the first chemistry laboratory in 1826.[29] Several sources, however, have indicated that other chemists may have introduced the use of the scientific laboratory before Liebig.[30] Lomonosov in Russia used the laboratory as an instructional technique as early as 1749, but, since he was outside the cultural center of Europe at the time, he was never given proper recognition for this innovation.[31] In the United States, laboratory instruction was first introduced in private laboratories before its adoption by American colleges. Public high schools in this country such as the Boston Girls' High and Normal School, and the Cambridge High School used this form of instruction when they included experiments as part of the chemistry course.[32]

In 1886, when Harvard University accepted chemistry for advanced placement, students seeking this status were required to complete a minimum number of experiments as listed in a pamphlet published by that institution. This list, which established laboratory work as an important aspect of chemistry education, was authored by Josiah Cooke.

> A pamphlet describing the kind of high-school course preferred and the type of experiments acceptable was written by Professor Josiah Cooke for distribution to the secondary schools of the country. In time, this little booklet and its subsequent editions came to be known, more in a whimsical than pejorative sense, as The Pamphlet. Under four major headings and 27 subheads were listed 83 experiments demonstrating both qualitative and quantitative aspects of laboratory chemistry.[33]

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[29] Ibid., p. 1548.

[30] George Lockemann and Ralph E. Oesper, "Frederick Stromeyer and the History of Chemical Laboratory Instruction," Journal of Chemical Education, XXX (April, 1953), p. 202.

[31] Aaron Ihde, "The Development of Scientific Laboratories," The Science Teacher, XXIII (November, 1956), p. 326.

[32] Rosen, "Rise of High-School Chemistry," pp. 628-9.

[33] Ibid., p. 629.

The New England Association of Chemistry Teachers deplored Josiah Cooke's pamphlet of recommended chemistry experiments and devoted several meetings to the topic. Numerous reports of the association were characterized by a resentment against Harvard University and Cooke's pamphlet, in particular.[34]

The prominent Committee of Ten in 1893 suggested that laboratory work be included in any sequence of science courses taught in the secondary school.[35] The need for organized laboratory instruction which would provide for direct experiences was expressed by the Committee of Ten in the following quotation:

> The report dwells repeatedly on the importance of the study of things and phenomena by direct contact. It emphasizes the necessity of a large proportion of laboratory work in the study of physics and chemistry, and advocates the keeping of laboratory note-books by the pupils, and the use of such note-books as part of the test for admission to college. At the same time the report points out that laboratory work must be conjoined with the study of a textbook and with attendance at lectures or demonstrations; and that intelligent direction by a good teacher is as necessary in a laboratory as it is in the ordinary recitation or lecture room. The great utility of the laboratory note-book is emphatically stated....[36]

Included in their recommendations was a tentative list of 100 experiments to be completed by chemistry students.[37]

As a result of the influence exerted by the colleges and national committees on the chemistry curriculum, the period from 1887 to 1900 was one in which laboratory instruction in chemistry achieved a popularity common to new ideas in education--a popularity prevalent in America, but

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[34]Rosen, "Rise of High-School Chemistry," p. 631.

[35]Sidney Rosen, "Innovation in Science Teaching-A Historical View," School Science and Mathematics, LXIII (April, 1963), p. 317.

[36]Sizer, "Secondary Schools at Turn of Century," p. 236.

[37]Fay, "History of Chemistry in American High Schools," p. 1553.

not elsewhere.[38] The experiments preceded classroom work, and students were expected to discover scientific principles for themselves. The "discovery method" became a fad, and little provision was made for lecture or discussion in the chemistry course.[39]

The popularity of the laboratory method caused Edwin Hall, who had authored a pamphlet in physics similar to the one that had been written for chemistry, to criticize the indiscriminate manner in which the laboratory was being adopted.[40]

From 1910 to 1950

Commencing with the early part of the twentieth century a schism developed between the secondary schools and colleges in reference to the type of curriculum being offered by the secondary schools. The following two factors, as enumerated by Brandwein, Watson, and Blackwood, contributed to the division that occurred between the two educational levels:

> First, the rapid expansion of secondary schools had produced a quantitative demand for teachers far in excess of the number of able new teachers available; as a result many classroom teachers were themselves unable to handle effectively the details recommended by the colleges. Second, and perhaps more important, was the expansion and change in the student body within the schools. Teachers realized that they were expected, under compulsory education laws and general public enthusiasm, to educate all American boys and girls. With a heterogeneous student body having diverse interests and abilities, the rigid high school chemistry course proposed by Cooke was no longer suitable; for many of these boys and girls were

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[38]Rosen, "Rise of High-School Chemistry," p. 631.

[39]Rosen, "Innovation in Science Teaching," p. 318.

[40]Ibid.

> not certain of completing high school, or were not necessarily going to any college, or found the chemistry course too difficult or uninteresting, or were not mentally equipped to master the many principles, facts, and quantitative aspects of the existing course.[41]

The worth of a subject in the early 1900's was still largely measured in terms of its value in training the mind (mental discipline). At the turn of the century, chemistry instruction with laboratory was reputed to have formal discipline value, and achieved a prestigious position in the curriculum similar to the one possessed by the subjects of math and Latin.[42] The preoccupation with mind training resulted in the subject of chemistry being irrelevant for most secondary chemistry students of the period. Some of the problems resulting from the emphasis on mental discipline in chemistry in the secondary school were summarized by Fay:

> This included to varying degrees reaction against college domination, against too much uniformity and standardization, against the lack of vital relationship between chemistry instruction and every-day life, against the dominance of the laboratory, against the over-emphasis on mathematics, against the disciplinary aim of education, against the logical organization of the subject matter, and against an arid and uninteresting presentation of it. Pupils were rebelling at these dry bones set before them.[43]

As one of the major objectives of the secondary school, mental discipline was eventually abandoned. One of the implied values of mental discipline was its power to train the mind in such a way as to promote transfer of training from one subject area to several others. It appeared,

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[41]Paul F. Brandwein et al., Teaching High School Science: A Book of Methods (New York: Harcourt, Brace & World and Company, 1958), p. 260.

[42]Fay, "History of Chemistry in American High Schools," pp. 1547-1550.

[43]Ibid., p. 1553.

however, that there was not even any transfer of training from the high school to the college chemistry course. For this reason, university and secondary school educators questioned the value of offering chemistry in the secondary school curriculum.

> In 1896, at a University of Chicago school and college conference, the following points were made: (1) students who had taken chemistry in high school did not perform better in the college course than those who had not; (2) if a student excelled in chemistry, the reason could usually be traced to special aptitude or special instruction; (3) the chief benefit of high-school chemistry seemed to be not the amount of information gained by the student, but rather that the material given was the same, essentially as that to which the student would be exposed in college.[44]

New objectives for the secondary school were formulated by various educational organizations, but the most influential list was published by the National Educational Association in 1918.[45] The list was prepared by the Commission on the Reorganization of Secondary Education and appeared in a publication entitled the Cardinal Principles of Secondary Education. The following objectives were enumerated in this list: "...1. Health. 2. Command of fundamental processes. 3. Worthy home membership. 4. Vocation. 5. Citizenship. 6. Worthy use of leisure. 7. Ethical character."[46] A committee under the leadership of Otis W. Caldwell[47] attempted to adapt

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[44] Rosen, "Rise of High-School Chemistry," p. 632.

[45] Fletcher G. Watson, "Teaching Science to the Average Pupil," The Science Teacher, XXXIV (March, 1967), p. 24.

[46] The Commission on the Reorganization of Secondary Education, Appointed by the National Education Association, Cardinal Principles of Secondary Education (Washington, D.C.: U.S. Government Printing Office, 1928), p. 5.

[47] J. Darrell Barnard, "Pre-1960 Contributions to Science Education," Science Education, LII (April, 1968), p. 240.

the methods and concepts of science to the seven cardinal principles. For this reason, an overriding theme of Caldwell's committee was an endeavor to relate science courses to the problems concerning the student's environment.[48]

The redefinition of goals undoubtedly encouraged the development of practical chemistry courses which were informational and utilitarian in character in order to meet the needs and interests of the pupils. One result was the emergence of textbooks which were repeatedly "watered down", and books with such titles as Physics of the Household, and Everyday Science with Projects appeared in the classroom.[49] It was widely believed that, due to the advancing technological age, students should study useful facts. "The pupils should learn something useful to them. Socially significant topics, such as 'Our Water Supply,' were introduced because when the well was near the barnyard, typhoid and other water-born diseases were commonplace."[50] Rosen has listed two developments that hastened this shift toward practical subjects--first, the Abraham Flexner experiment at the Lincoln School in New York in which students enrolled in a vocational curriculum, and second, the Smith-Hughes Vocational Bill which enabled public schools to prepare students for occupations in the business world.[51]

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[48] Fay, "History of Chemistry in American High Schools," p. 1554.

[49] Claude Gatewood, "The Science Curriculum Viewed Nationally," The Science Teacher, XXXV (November, 1969), p. 18.

[50] Watson, "Teaching Science to Average Pupil," p. 24.

[51] Rosen, "Rise of High-School Chemistry," p. 632.

Two courses in chemistry began to evolve, one for the college preparatory student, the other for the terminal high school pupil. The practical course (terminal chemistry) employed the use of laboratory manuals, many of which contained instructions for measuring quantities in spoonfuls instead of cubic centimeters.[52] This evolution in practical chemistry courses took place since educators were left with the task of adapting the left-over curriculum materials to the seven cardinal principles as proposed by the National Educational Association. Furthermore, scientists had generally lost interest in overseeing the content of the secondary school chemistry course. At about the same time, new teaching techniques were being introduced such as, the project method, visits to industrial plants, chemistry clubs, outside readings, sectioning classes on the basis of intelligence and standardized tests in the high school chemistry class.[53] Laboratory work became practical rather than theoretical.

During the first half of the twentieth century a gradual decrease in the popularity of the scientific laboratory occurred. Brandwein summarized the reduction in laboratory instruction in the following words:

> However, up to the time of the earth satellite the amount of <u>time</u> given over to laboratory work as compared with demonstration work seemed to be decreasing. We noted, for instance, fewer and fewer double lab periods, and more and more demonstration work suggested in published curriculums. We noted a tendency to build <u>fewer</u> laboratories in the new schools, although some laboratories are included in all schools....[54]

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[52]Ibid.

[53]Fay, "History of Chemistry in American High Schools," p. 1555.

[54]Brandwein et al., <u>Teaching High School Science</u>, p. 209.

According to Swinnerton, this decline was spurred by advocates of the lecture-demonstration method of instruction.[55] In addition, laboratories decreased in number since administrators questioned their usefulness. Reasons given for doing away with laboratories included, among others, the fact that they were too expensive, double periods were difficult to schedule, and they were not practical for those students who were terminating their education.[56]

The rejection of the high school science laboratory as an educational tool was partially supported by research. Research studies had compared the lecture-demonstration method with the laboratory method and based their results on paper and pencil tests that measured factual information.[57] These tests tended to show that the student did not gain in increased knowledge of chemistry by participating in laboratory work. Since these findings indicated no improvement in achievement, the advocates of the lecture-demonstration method maintained that large amounts of money could be saved by doing away with individual laboratory work.[58] Downing drew the following conclusions about the lecture-demonstration method of instruction:

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[55]Carl P. Swinnerton, "Evaluation of Laboratory Work in Chemistry," Journal of Chemical Education, XXXI (January, 1954), p. 44.

[56]Leonard A. Ford, "Laboratory Science," School Science and Mathematics, XL (June, 1940), p. 556.

[57]C.H. Walter, "The Individual Laboratory Method of Teaching Physics When No Printed Directions are Used," School Science and Mathematics, XXX (April 30, 1930), p. 429.

[58]W.C. Croxton, "Shall Laboratory Work in the Public Schools be Curtailed?", School Science and Mathematics, XXIX (January, 1929), p. 79.

> The lecture-demonstration method of instruction yields better results than the laboratory method in imparting essential knowledge and is more economical of time and expense. This is true for both bright and dull pupils and for all types of experiments. The last two points need additional experimental confirmation.
>
> The lecture-demonstration method appears to be the better method for imparting skill in laboratory technique in its initial stages and for developing ability to solve new problems. Again, these two items are tentative conclusions, and further experiments will be required to establish them.[59]

The few experiments that were still being conducted by the students during this period were usually for the purpose of verifying information that had been learned in the classroom. Since the student had been told what to do and what to expect, the emphasis was placed on "getting" the right answer. Nichols recognized this problem when she reported the following:

> The question is how far laboratory as now carried on in secondary schools and colleges is essential to the purpose of inducing students to use their own intellects. This topic has recently aroused a good deal of interest among teachers of science and is one which deserves serious consideration.
>
> The usual way of conducting laboratory work is to put into the hands of the student a laboratory manual or sheet of directions which he must follow in order to produce the expected result. Subsequently he reads an assignment in a text-book and listens to a lecture.[60]

One of the reasons the lecture-demonstration method of instruction gained widespread acceptance was due to the fact that the presentation of factual information was oftentimes accomplished more efficiently in the lecture-demonstration method than in the laboratory method of instruction. There were, however, critics of the lecture-demonstration method as well as

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[59]Elliot Downing, "A Comparison of the Lecture-Demonstration and the Laboratory Method of Instruction in Science," _The School Review, A Journal of Secondary Education_, XXXIII (November, 1925), p. 697.

[60]Louise M. Nichols, "Getting the Student to Use His Own Intellect," _Science_, LXXIV (August 7, 1931), p. 152.

proponents. One author felt that the demonstration method was ineffectual in presenting material to the student: "..., for instead of students' learning chemistry by experimenting, the high school teacher 'takes the course' as he stands before his class performing a few experiments. Oftentimes, students in the last row wonder just what is really taking place on the teacher's demonstration desk."[61] Other authors were not convinced that laboratory work should be excluded from the curriculum. Levelle thought that studies of the effectiveness of the science laboratory had been too largely concerned with the acquisition of factual information and that educators had not found a way of measuring the intangible assets which a student develops in the course of his laboratory experience.[62] Boeck concluded that in the high school chemistry laboratory students could develop a knowledge of and skill in the use of the scientific method, if they were intimately involved in the planning of experiments.[63] Furthermore, in 1941 Wessell expressed the opinion that the demonstration method did not allow students to display proper scientific attitudes.

> Pupils are not forced to make judgements and then revise them or discard them on the basis of facts brought to light in the scientific

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[61] Virginia W. Fisher, "Post-War High School Chemistry," Journal of Chemical Education, XXII (December, 1945), p. 594.

[62] J.M. Levelle, "The Laboratory-Pro and Con," School Science and Mathematics, XXXIX (October, 1939), p. 646.

[63] Clarence H. Boeck, "Teaching Chemistry for Scientific Method and Attitude Development," Science Education, XXXVII (March, 1953), p. 81.

method. Teachers are not directing their pupils to display proper scientific attitudes or to employ a method of thinking as much as they are to the accumulation of facts or information.[64]

From 1950 to the Present

In the years immediately preceding the 1950's much of the material included in chemistry textbooks and taught in the chemistry classroom was outmoded. New topics in chemistry had been added to existing textbooks in the form of additional chapters.[65] No major revisions in chemistry content had occurred, since educational materials were usually written by science educators who were not always entirely cognizant of recent information in chemistry.[66] This caused a deplorable situation which Pode claimed necessitated major content changes in chemistry for the following reasons:

> (1) Courses were too large, built up by a process of accretion, and impossible to finish without a terrible rush; no one seemed to take into consideration that it was no longer possible to know--and even less possible to teach--more than a fragment of any one field of knowledge.
> (2) Courses were too factual, and textbooks had become unreadable encyclopedias of "essential information."
> (3) Laboratory work was almost always a tepid demonstration of what the student knew already.[67]

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[64] George Wessell, "Measuring the Contribution of the Ninth Grade General Science Course to the Development of Scientific Attitudes," Science Education, XXV (November, 1941), p. 339.

[65] John I. Goodlad, The Changing School Curriculum, A Report from the Fund for the Advancement of Education, 1966 (New York: The Fund for the Advancement of Education, 1966), p. 14.

[66] Claude W. Gatewood and Ellsworth S. Obourn, "Improving Science Education in the United States," Journal of Research in Science Teaching, I (1963), p. 359.

[67] J.S.F. Pode, "CBA and CHEM Study: An Appreciation," Journal of Chemical Education, XLIII (February, 1966), p. 98.

The early 1950's saw the inauguration of major changes in chemistry curriculum content and teaching methods. The National Science Foundation supported projects such as CHEM Study and the CBA Project. "At the beginning of the NSF support, it was made clear by the project directors that the objective of each program was to make a careful and complete restudy of the chemistry program; it was not to be a patchwork job on the present curriculum."[68] The curriculum projects have presented, for the teacher's use, a package of instructional materials which have included a textbook, workbooks, teacher's manuals, film strips, films, and laboratory experiments. This has meant that the teacher has been "...teaching better chemistry through the use of revitalized, revised textbooks along with using realistic and open-ended laboratory exercises."[69]

These projects, along with the impetus generated as a result of Russia's earth satellite, influenced laboratory programs in the secondary schools. An attempt was made in the new programs to focus on the laboratory as an important facet of instruction where the student should have the opportunity to observe phenomena and to use the methods of the scientist in working with these phenomena.[70]

Both CHEM Study and CBA have attempted to present science as inquiry. An effort was put forth to accomplish this goal by giving the student first-

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[68]Alfred Garrett, "The New Chemistry," The Science Teacher, XXVIII (April, 1961), p. 15.

[69]Lloyd M. Bennett and Barbara K. Pyke, "A Discussion of the New Chemistry Programs (CHEMS and CBA) and the Traditional Programs in High School," School Science and Mathematics, LXVI (December, 1966), p. 824.

[70]Goodlad, The Changing School Curriculum, p. 14.

hand experience with phenomena in the laboratory and by encouraging the student to discover ideas and develop the viewpoints of scientists. As a result, the two programs have had the intended purpose of allowing for student discovery rather than having students verify stated principles.[71]

This renewed emphasis upon the chemistry laboratory occurred since certain aspects of scientific inquiry (observation, interpretation, prediction) could be practiced to advantage in this setting.[72] Goodlad has summarized the type of laboratory experiences that the newly developed curricula are attempting to provide for the student:

> The course emphasizes laboratory work, which is designed to develop in the student the ability to identify a problem, to design an experiment that will shed light on this problem, to carry out the technical operations of the experiment, and to arrive at a conclusion based on analysis of his own data. Assistance is gradually withdrawn until the student finally performs all of the steps independently, employing techniques he has learned from exploration of earlier problems.[73]

In the CBA laboratory manual it is stated that the student should gain an understanding of the scientific enterprise and its methods.[74] Though the CHEM Study course has endorsed those same aims, its approach is different from that of the CBA course.[75] The importance of student participation in the experimentation process is stated in the foreword to CHEMISTRY - An Experimental Science:

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[71] Gatewood and Obourn, "Improving Science Education," p. 326.

[72] Alfred Novak, "Scientific Inquiry in the Laboratory," The American Biology Teacher, XXV (May, 1963), p. 346.

[73] Goodlad, The Changing School Curriculum, p. 45.

[74] Chemical Bond Approach Project, Investigating Chemical Systems (New York: McGraw-Hill Book Company, Inc., 1963), p. 1.

[75] Pode, "CBA and CHEM Study," pp. 99-100.

The title, CHEMISTRY - An Experimental Science, states the theme of this one year course. A clear and valid picture of the steps by which scientists proceed is carefully presented and repeatedly used. Observations and measurements lead to the development of unifying principles and then those principles are used to interrelate diverse phenomena. Heavy reliance is placed upon laboratory work so that chemical principles can be drawn directly from student experience. Not only does this give a correct and nonauthoritarian view of the origin of chemical principles but it gives maximum opportunity for discovery, the most exciting part of scientific activity.[76]

Importance of the Problem

The National Science Teachers Association[77] and other authorities have proposed that the student participate directly in scientific inquiry. They have maintained that the student should be given a chance to improvise equipment, to observe, and to experiment. That is, the student should have an opportunity to take part in the scientific enterprise and in the investigation of problems whose solutions are unknown to him.[78] In Rethinking Science Education the understanding of the nature of the scientific enterprise and its methods were recommended. It was stated in this volume that the student should spend more time attacking laboratory problems and developing insight into how data should be processed and interpreted.[79] Furthermore, one of the major criticisms of previous laboratory work was

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[76]Chemical Education Material Study, CHEMISTRY-An Experimental Science (San Francisco: W.H. Freeman and Company, 1963), p. 7.

[77]National Science Teachers Association, Planning for Excellence in High School Science (Washington, D.C: National Education Association), p. 45.

[78]Robert B. Smith, "A Break with Instructional Traditions in Organic Chemistry," Journal of Chemical Education, XLIV (March, 1967), p. 149.

[79]National Society for the Study of Education, Rethinking Science Education, Fifty-Ninth Yearbook of the National Society for the Study of Education, Part I (Chicago: The University of Chicago Press, 1960), p. 334.

the failure to provide genuine problem-solving experiences.[80] In a publication of the National Science Teachers Association a committee has succinctly expressed the need for research dealing with the nature of laboratory experiments provided for students:

> Many high school science laboratory programs are a sorry shadow of what they might be. In some cases, growth toward appreciation for, enthusiasm about, and understanding for the process of science is negative rather than positive. In general, high school science laboratory learning needs great improvement; moreover, intense research leading to such improvement is sorely needed.[81]

The new high school curricula have placed more emphasis on the "discovery" type of laboratory programs. Pode claimed that these new laboratory programs emphasize the following questions: "To what problems can an answer be sought experimentally? What data are relevant? How may observations be made quantitative? How can the data best be ordered for interpretation?"[82]

This shift towards inquiry training has a philosophical basis in writings produced by Bruner and Schwab. Bruner has hypothesized that the child should be his own discoverer and should put things together for himself. He has expressed the opinion that discovery takes place when the student learns for himself even if the learning is not original. The key to discovery for Bruner lies in the fact that what is learned can not be

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[80] George G. Charen, "Laboratory Methods Build Attitudes," Science Education, L (February, 1966), p. 54.

[81] National Science Teachers Association, Planning for Excellence in High School Science, p. 45.

[82] Pode, "CBA and CHEM Study," p. 98.

previously known by the person doing the discovering.[83] Schwab too is an advocate of laboratory work that allows the student to be inventive.

> The laboratory is easily converted to enquiry and happily, good work in this area has been initiated. In general, the conversion takes place by having the laboratory lead rather than lag the classroom phase of science teaching.... It ceases, too, to be preoccupied with standardized techniques. It becomes, instead, a place where nature is seen more nearly in the raw and where things seen are used as occasions for the invention and conduct of programs of enquiry. The laboratory manual which tells the student what to do and what to expect is replaced by more permissive and open material.[84]

The inquiry* method is as controversial today as the lecture-demonstration method was in past years. Uncertainty has been expressed over the necessity of inquiry in the laboratory especially if it becomes the principle method of instruction. Both Ausubel and Gagné have stated their disagreement with the adoption of the inquiry method as the foremost mode of instruction for students:

> Hence, although laboratory work can easily be justified on the grounds of giving students some appreciation of the spirit and methods of scientific inquiry, and of promoting problem-solving, analytic, and generalizing ability, it is a very time-consuming and inefficient practice for routine purposes of teaching subject-matter content or of illustrating principles, where didactic exposition or simple demonstration are perfectly adequate. Knowledge of the methods whereby data and principles in a particular discipline are acquired need not necessarily be gained in all instances through self-discovery in the laboratory. In many situations, this purpose can be accomplished much more efficiently through didactic exposition in conjunction with demonstrations and paper-and-pencil exercises.[85]

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[83] Jerome S. Bruner, "The Act of Discovery," in Inquiry Technique for Teaching Science, ed. by William D. Romey (Engelwood Cliffs, New Jersey: Prentice-Hall Inc., 1968), p. 160.

[84] Joseph J. Schwab, "Enquiry, the Science Teacher, and the Educator," The Science Teacher, XXVII (October, 1969), p. 9.

[85] David P. Ausubel, "An Evaluation of the Conceptual Schemes Approach to Science Curriculum Development," Journal of Research in Science Teaching, III (1965), pp. 262-3.

*This form of the word inquiry has been utilized by the investigator in the text, although two forms are recognized as acceptable.

If there are any limitations to the value of practice in enquiry, they are probably to be found in this fact: such practice is not the whole story. Establishing conditions for practice in enquiry does not by any means exhaust the requirements for the instructional conditions needed for the achievement of the desired terminal capability. And there are real dangers in thinking that such practice does constitute the entire set of requirements for this purpose.[86]

We have not had and still do not have an effective means of evaluating this instructional technique. In the ensuing quotations Watson, Ramsey, and Rowe have stressed a need to determine the types of laboratory activities in which students should engage when studying science:

Careful study of the results of laboratory work, individual or in small groups, is especially important at this time. The several nation-wide committees suggesting modifications in high school science courses are all stressing the importance of first-hand experience with the phenomena. With them, we agree that this experience seems essential in the study of science. Yet, to provide time, space, and materials for this laboratory work is expensive. Without clear empirical evidence of what sorts of experiences result in what subsequent behaviors, or enhanced behaviors, in pupils, we are of necessity proceeding on faith. This is hardly the strongest basis on which to convince school administrators and school boards that the investment needed will produce desired results.[87]

That the experiences possible for students in a laboratory situation should be an integral part of any science course has come to have wide acceptance in our science teaching. What the best kinds of experiences are, however, and how these may be blended with more formal classwork, has not been objectively evaluated to the extent that clear direction based on research is available to the teacher.[88]

It has been suggested, and indeed it is the trend in many of the course improvement projects, to make laboratory experiences central

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[86]Robert M. Gagné, "The Learning Requirements for Enquiry," Journal of Research in Science Teaching, I (1963), p. 147.

[87]Fletcher G. Watson, "Research on Teaching Science," in Handbook of Research on Teaching, ed. by N.C. Gage (Chicago: Rand, McNally & Company, 1963), pp. 1043-4.

[88]Gregor A. Ramsey and Robert W. Howe, "An Analysis of Research on Instructional Procedures in Secondary School Science," The Science Teacher, XXXVI (April, 1969), p. 75.

> to instructional procedures in science. Yet direct research on what these experiences should be, how they should be organized, and where they function best, is indeed meager.[89]

If, as past studies have tended to show, laboratory work does not raise the achievement level of the student, then its inclusion in the science curriculum must be defended on other bases. Laboratory work may increase the students' understanding of science as outlined by the National Science Teachers Association,[90] and it may contribute to improvement in scientific attitude. Furthermore, Bruner has stated in the following that attitudes are an important part of the learning process:

> Mastery of the fundamental ideas of a field involves not only the grasping of general principles, but also the development of an attitude toward learning and inquiry, toward guessing and hunches, toward the possibility of solving problems on one's own.... To instill such attitudes by teaching requires something more than the mere presentation of fundamental ideas. Just what it takes to bring off such teaching is something on which a great deal of research is needed,...[91]

Synopsis of the Problem

Most secondary schools, because of tradition, have been equipped with science laboratories. Laboratory instruction has always been an integral part of the secondary school science curriculum. For the purpose of improving existing laboratory facilities and enriching laboratory instruction, federal money has been made available for the purchase of scientific

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[89]Ibid., p. 76.

[90]National Science Teachers Association, Planning for Excellence in High School Science, p. 45.

[91]Jerome S. Bruner, The Process of Education (New York: Vintage Books, 1960), p. 20.

equipment and the development of curriculum projects. The renewed emphasis upon the chemistry laboratory has occurred in spite of the fact that the literature has revealed that the laboratory has been a controversial and unproven educational tool in the secondary school. This indicates that science laboratories are operated largely on the basis of faith.

Most studies, until recently, have concentrated on comparing the achievement level of students who have had laboratory instruction with those who have been exposed to some other method of teaching. This emphasis upon achievement represents a narrow band on the total spectrum of educational purposes, but is is used since it is the easiest to measure. Achievement is just one factor to be considered in the evaluation process and undoubtedly is too restrictive a unit of comparison. Other factors, such as student attitudes towards science and understanding of science, should also be considered. It would seem logical to assume that the high school student who practices the discovery approach in the chemistry laboratory should have a better attitude toward science, a better understanding of science, and a better understanding of the methods and aims of science. In this study an attempt will be made to evaluate student laboratory behaviors associated with the discovery process and their relationship to an improved attitude toward science, an understanding of science, and an understanding of the methods and aims of science.

Statement of the Problem

The present study will attempt to assess the importance of the contribution of certain behaviors as exhibited by students in the chemistry laboratory to an understanding of science, an understanding of the methods and aims of science, and to the development of an improved attitude toward science, as measured by the Test on Understanding Science, Part III of the Test on Understanding Science, and the Vitrogan Attitude Scale.

Purpose of the Study

1. To delineate a list of behavioral practices related to an understanding of science, an understanding of the methods and aims of science, and an improved attitude toward science, as recommended by science educators that students should perform in the chemistry laboratory. These recommended activities will be obtained from the literature, and will be written in behavioral terms as suggested by Kurtz, Andersen, Montague and Butts.[92]

2. To determine those behavioral practices that contribute most to an improved scientific attitude, an understanding of science, and an understanding of the methods and aims of science, as measured by VAS, TOUS and Part III of TOUS. This will be done by using an F ratio (one-way analysis of variance) which will permit the assessment of the importance of each individual item in the list of behavioral practices.

Hypothesis

When students in chemistry laboratory classes are evaluated in

[92]Earl J. Montague and David P. Butts, "Behavioral Objectives," The Science Teacher, XXXV (March, 1968), pp. 33-5; Edwin B. Kurtz, Jr., "Help Stamp Out Non-Behavioral Objectives," The Science Teacher, XXXII (January, 1965), pp. 31-2; Hans O. Andersen, "Preparing Performance Objectives in Science Education for the Secondary School," in Readings in Science Education for the Secondary School, ed. by Hans O. Andersen (New York: The Macmillan Company, 1969), pp. 154-7.

terms of behavioral practices (see Appendix C), there should be a significant difference between groups of students who exhibit certain behaviors specified in the list of behavioral practices and groups of students who do not. This difference will be determined by means of the following set of criteria:

1. A positive attitude toward science and scientists, as measured by VAS.

2. An understanding of the nature and processes of science, as measured by TOUS.

3. An understanding of the methods and aims of science, as measured by Part III of TOUS.

The following null hypotheses will be tested for significance at the .05 level.

1. There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit certain behaviors specified in behavioral practices 1, 2, ... 18, and those groups of students who do not exhibit certain behaviors specified in behavioral practices 1, 2, ... 18.

2. There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit certain behaviors specified in behavioral practices 1, 2, ... 18, and those groups of students who do not exhibit certain behaviors specified in behavioral practices 1, 2, ... 18.

3. There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of

students who exhibit certain behaviors specified in behavioral practices 1, 2, ... 18, and those groups of students who do not exhibit certain behaviors specified in behavioral practices 1, 2, ... 18.

Limitations of the Problem

Conclusions derived from the results of the present study are in all probability qualified by the following:

1. Testing instruments--the presumption that for this study _TOUS_ and _VAS_ are suitable instruments for measuring the students' understanding of science, understanding of the methods and aims of science, and improved attitude toward science.

2. Present science course--the presumption that the students' understanding of science, understanding of the methods and aims of science, and improved attitude toward science, as measured by _TOUS_ and _VAS_, are enhanced when certain behaviors are practiced in the laboratory.

3. Observers--the presumption that the two raters had the capability to objectively rate each behavioral practice.

4. Observations--the presumption that each student behavioral practice, as rated by the evaluators, was representative of student performance throughout the academic year in similar laboratory settings.

5. Population--the presumption that the sample population utilized was large enough. Eleven high school chemistry classes participated in this study; the classes ranged in size from twelve to forty.

6. Selection of classes--the presumption that the evaluators selected classes that exhibited either a high or a low degree of student involvement in the laboratory. No attempt was made to control the student

population in each class.

7. Geographic location--the presumption that the laboratory classes, located in Massachusetts and New Hampshire, represented a sufficient geographic distribution.

Definition of Terms

1. Process of Inquiry--synonyms include "scientific method, scientific methods, problem solving, problem doing, discovery, inquiry, processes of the scientist, processes of science, strategies for inquiry, strategies for problem solving, the 'methods of intelligence'."[93]
2. Understanding of Science--this term is defined by Cooley and Klopfer in their report on the HOSC Instruction Project. "Such understandings have frequently been referred to as 'appreciations' of 'intangibles' and include understanding by students of science as an institution, of scientists as people, of the aims of science, and of the processes of science."[94]

> A student should learn something about the character of scientific knowledge, how it has been developed, and how it is used. He must see that knowledge has a certain dynamic quality and that it is quite likely to shift in meaning and status with time.
> A student with a liberal education in science should be able to appreciate:
> 1. The importance of science for understanding the modern world.
> 2. The methods and procedures of science for their value in discovering new knowledge and extending the meaning of previously developed ideas.

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[93]Paul F. Brandwein, "Observations on Teaching: Overload and Methods of Intelligence," The Science Teacher, XXXVI (February, 1969), p. 38.

[94]Leopold E. Klopfer and William W. Cooley, "The History of Science Cases for High Schools in the Development of Student Understanding of Science and Scientists," A Report on the HOSC Instruction Project, Journal of Research in Science Teaching, I (1963), p. 33.

3. The men who add to the storehouse of knowledge.
4. The intellectual satisfaction to be gained from the pursuit of science either as a scientist or as a layman.[95]

3. Behavioral Objectives--"a behavioral objective is a goal for, or a desired outcome of, learning which is expressed in terms of observable behavior (or performance, if you prefer) of the learner."[96]

> First there is something we may call a terminal capability, something that the student is able to do after he has learned. That is to say, if we have been successful in establishing the correct conditions for learning, we will be able to infer that the student is or is not capable of employing the methods of scientific enquiry. To make this inference possible, of course, we must observe some kinds of behavior, which may also be specified, and we might refer to these observed events as terminal behaviors.[97]

4. Attitudes--Attitudes regulate behavior that is directed toward or away from some object or situation or groups of objects, or situations. Attitudes have emotional content and vary in intensity and generality according to the range of objects or situations over which they apply. For the most part, attitudes are learned and are difficult to distinguish from such affective attributes of personality as interests, appreciations, likes, dislikes, opinions, values, ideals, and character traits.[98]

5. Scientific Attitude--Some of the components of scientific attitude are:

> ...4. controlled observation will be distinguished from casual observation
> 5. constant change will be stressed over nonchange; a basic notion that reality is to be regarded as a process implying continuous change; no two things are exactly alike, no one thing stays the same
> 6. structure in the form of relations and equations will be stressed over function; structure, the nature of the phenomenon, the broad unifying principle is stressed rather than application (detail) or function

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[95]National Society for the Study of Education, Rethinking Science Education, pp. 34-6.

[96]Montague and Butts, "Behavioral Objectives," p. 33.

[97]Gagné, "Learning Requirements for Enquiry," p. 145.

[98]Richard E. Haney, "The Development of Scientific Attitudes," The Science Teacher, XXXI (December, 1964), p. 33.

7. greater concern for research rather than findings; greater emphasis on the inquiring, the questionning rather than the final answers obtained; the form of the question is considered more important than the answer observed...[99]

6. Laboratory--room where laboratory exercises are performed. Basically, laboratory exercises are done or performed as a means of practice or training. Common usage often fails to distinguish between laboratory exercises and experiments. Experiments are tests or trials, tentative procedures, acts or operations for the purpose of discovering something unknown or testing a principle supposition. Obviously, laboratory exercises can provide practice or training in designing, operating, and interpreting experiments, but they are quite likely to be contrived pedagogical devices and, as such, should be clearly distinguished from experimentation as it exists in the pursuit of science. Well designed and conducted laboratory exercises, however, can incorporate much of the spirit and many of the skills of experimentation.[100]

7. VAS--Vitrogan Attitude Scale.

8. TOUS--Test on Understanding Science.

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[99] David Vitrogan, "Origins of the Criteria of a Generalized Attitude Toward Science," Science Education, LI (March, 1967), p. 175.

[100] Woodburn and Obourn, Teaching the Pursuit of Science, pp. 366-7.

CHAPTER II

RELATED STUDIES

Introduction

During the period from 1912 to 1969 the teaching methods employed in the science laboratory were the subject of investigation in numerous research studies. Early studies were primarily concerned with comparisons between the lecture-demonstration method and the laboratory method of instruction. The preferability of either the lecture-demonstration method or the laboratory method, as a form of instruction, was usually determined by measuring the students' attainment of knowledge.

Unfortunately, research dealing with the effectiveness of the scientific laboratory diminished during the period from 1946 to 1960. Recently, however, there has been a renewed interest in determining the value of the scientific laboratory. In light of this, attention has been focused on various other factors (critical thinking, development of scientific attitudes, and understanding of the scientific enterprise) in addition to knowledge achievement. Since, in many studies, several of the variables have been investigated simultaneously, the studies have been arranged in chronological order.

Review of Related Literature

The research comparing the lecture-demonstration method (students watched instructor perform experiments) with the individual laboratory method (students performed their own experiments) for the period from 1912 to 1943 was reviewed by Cunningham.[1] According to Cunningham, the investigators often failed to control all the variables that might have affected their studies. Among the variables which were frequently uncontrolled within the studies were: (1) complexity of the experiments performed by students, (2) age of pupils, (3) length of time that students had to work on experiments, (4) sex of students, (5) previous science courses completed by students, (6) the time required to complete a demonstration in comparison to the time needed to perform an experiment, and (7) whether or not the experimental and control groups had the same teacher. Cunningham found a trend in the studies which indicated that pupils who observed lecture-demonstrations prior to performing experiments in the laboratory achieved slightly better results on subsequent laboratory work than those students who did not receive lecture-demonstration instruction. In addition, the subject was more fully covered by the demonstration method. As reported by Cunningham the studies comparing the lecture-demonstration with the laboratory method are summarized in Table A.

Among the studies included in Cunningham's review was a landmark study by Horton.[2] This investigation had been executed in two phases. In phase one a comparison had been made between the demonstration method (instructor performed experiments by following directions in laboratory manual) and the individual laboratory method (students followed directions

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[1]Harry A. Cunningham, "Lecture-Demonstration versus Individual Laboratory-A Summary," Science Education, XXX (March, 1946), pp. 70-82.

[2]Ralph E. Horton, "Measured Outcomes of Laboratory Instruction," Science Education, XIV (November, 1929), pp. 311-19; XIV (January, 1930), pp. 415-21.

TABLE A

SUMMARY OF STUDIES INCLUDED IN CUNNINGHAM'S REVIEW (1912-1943)

Factor Investigated	Number of Studies in which Factor was Investigated	Number of Studies Indicating Method Superior for Factor Investigated		Number of Studies Showing No Significant Difference Between Methods
		Lecture-Demonstration Method	Laboratory Method	
1. Immediate Recall of Information	28	20	6	2
2. Delayed Recall of Information	24	10	11	3
3. Interest Stimulated in Pupils	7	3	4	0
4. Most Efficient Use of Time in Completion of Work	15	15	0	0
5. Laboratory Resourcefulness	1	0	1	0
6. Laboratory Manipulation of Equipment	4	0	4	0
7. Providing for Individual Differences	4	1	3	0
8. Scientific Thinking	17	12	4	1

in laboratory manual). A written examination had been administered which revealed no significant differences between the two groups. In addition, a series of performance tests had been given to determine student ability to manipulate apparatus and perform experiments. On the basis of this data Horton had concluded that: (1) the written test had not disclosed all the outcomes of individual laboratory work; (2) some of the outcomes had been of a manipulative and practical nature; and (3) students who had had laboratory practice acquired these outcomes better than those who had been exposed to the teacher-demonstration form of instruction. In a second phase of the study, Horton had investigated the development of scientific thinking. The experimental group had utilized the problem-solving method in the laboratory which permitted students to set up apparatus, to find out information for themselves, and to devise experiments for the purpose of verifying or disproving assertions or assumptions. The control groups had followed directions printed in a laboratory manual. Student performance had been measured by a series of tests which included: (1) a written achievement test, (2) a written test of chemical judgment, (3) a performance test to evaluate student ability to manipulate apparatus, and (4) a performance test to measure student ability to perform projects in the laboratory. From this data Horton had concluded that individual laboratory work planned by the student was superior to laboratory work in which students were instructed to follow instructions in a chemistry laboratory manual.

Noll's[3] interest in scientific attitude development led him

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[3]Victor H. Noll, "Measuring the Scientific Attitude," The Journal of Abnormal and Social Psychology, XXX (July-September, 1935), pp. 145-54.

to construct a number of different forms of a test to measure scientific attitude. Wessell[4] continued this work with an investigation into the scientific attitudes of ninth grade science students. With an instrument devised by Wessell to measure scientific attitude, 147 ninth grade science students were pre-tested and post-tested. On the basis of this information Wessell concluded that ninth grade science does contribute to attitude development but not as much as might be expected. In light of this, Wessell theorized that ninth grade science instructors, in emphasizing the accumulation of facts, did not encourage students to form and revise judgments as new facts were discovered.

Barnard[5] completed a study on the college level in which he compared a lecture-demonstration method with a problem-solving method. The lecture-demonstration method consisted of formal lectures with demonstration, whereas the problem-solving method (as employed in Barnard's study) permitted student participation in formulating problems studied in class and student participation in analyzing proposed solutions. Pairing of students was accomplished by means of scores on psychological tests and pre-tests. In addition, achievement tests were given that measured recall of specific information, understanding of generalizations, abilities in problem-solving and

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[4]George Wessell, "Measuring the Contribution of the Ninth Grade General Science Course to the Development of Scientific Attitudes," Science Education, XXV (November, 1941), pp. 336-9.

[5]J. Darrell Barnard, "The Lecture-Demonstration Versus the Problem-Solving Method of Teaching a College Science Course," Science Education, XXXI (April, 1947), pp. 175-8.

scientific attitudes. On the basis of a statistical analysis of the results, Barnard concluded that: (1) the lecture-demonstration method was superior in teaching factual information but the two methods could be equated when considered in terms of understanding generalizations; and (2) the problem-solving method was superior in the development of problem-solving ability and scientific attitudes. The relationship between student behavior and the understanding of generalizations, abilities in problem-solving, and scientific attitudes were recommened for further investigation by Barnard.

Two groups of high school biology students were compared by Mallinson[6] in an attempt to determine the effectiveness of the lecture-demonstration method and the laboratory method of instruction. Mallinson deduced that students were better prepared for the New York State Biology Regents examinations when enrolled in a course with laboratory than students who were enrolled in a lecture-demonstration course without laboratory.

In 1949 Anderson[7] conducted a study in which he sought to determine the extent to which the following objectives were being pursued in high school chemistry classes in Minnesota: (1) the understanding of the principles of science, (2) the understanding and use of the scientific method, (3) the acquisition of factual information in science, and

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[6]George G. Mallinson, "The Individual Laboratory Method Compared with the Lecture-Demonstration Method in Teaching General Biology," Science Education, XXXI (April, 1947), pp. 175-9.

[7]Kenneth E. Anderson, "Summary of the Relative Achievements of the Objectives of Secondary School Science in a Representative Sampling of Fifty-Six Minnesota Schools," Science Education, XXXIII (December, 1949), pp. 323-9.

(4) the acquisition of scientific attitudes. Information was obtained on the backgrounds of both teachers and pupils. From an analysis of the data, it was concluded that the following factors were related to the development in students of the aforementioned objectives:

> (1) The teacher was in the upper one-fourth of the distribution in terms of quarter-hours of college chemistry earned,
> (2) the pupils used a laboratory manual,
> (3) the pupils elected chemistry,
> (4) the number of laboratory hours received by the pupils was in the upper one-fourth of the state distribution.
> (5) the teacher had graduated from a university or private college rather than a teachers college, and
> (6) the pupils were in a class the size of which was in the upper one-fourth of the state distribution....,
> ....
> (1) the pupils were in a large-sized school or medium-sized school rather than in a small-sized school....,
> (2) the teacher had ten or more years of experience teaching chemistry....,
> (3) the teacher had one or two preparations rather than six preparations per day....,
> (4) the teacher's knowledge of the scientific method placed her in the upper one-fourth of that distribution....[8]

Using the end scores for statistical analysis, significance was noted for the following factors: (1) student intention to continue his education, and (2) the number of quarter-hours of college science earned by the students' teacher. In addition, Anderson concluded that the following three factors were not important for student understanding of science and an improved scientific attitude: (1) the sex of the teacher, (2) the time of day in which laboratory instruction took place, and (3) whether or not the teacher possessed a Master's degree.

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[8] Ibid., p. 328.

Kruglak[9] compared the lecture-demonstration method with the laboratory method of teaching. The results of his study led him to conclude that: (1) the physics laboratory was better than the lecture-demonstration method for teaching instrumental techniques and solving simple problems that required apparatus; and (2) neither method proved superior for teaching the solving of complex laboratory problems or for influencing student scores on paper and pencil tests that covered classroom material.

Student behaviors that might contribute to certain inductive aspects of scientific thinking in college biology were identified by Burmester.[10] By administering an examination, an attempt was made to evaluate student behaviors such as the ability to recognize problems, hypotheses, and experimental conditions. The test was administered to students who enrolled in a biological science course and to students who had not enrolled in a biological science course at Michigan State. After analysis of the results, it was concluded that students who completed the biology course demonstrated increased ability to think scientifically.

One group in inductive-deductive chemistry was contrasted with another group in deductive-descriptive chemistry by Clarence H. Boeck.[11]

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[9]Haym Kruglak, "A Comparison of the Conventional and Demonstration Methods in the Elementary College Physics Laboratory," Journal of Experimental Education, XX (March, 1952), pp. 293-300.

[10]Mary Alice Burmester, "Behavior Involved in the Critical Aspects of Scientific Thinking," Science Education, XXXVI (December, 1952), pp. 259-63; "The Construction and Validation of a Test to Measure Some of the Inductive Aspects of Scientific Thinking," Science Education, XXXVII (March, 1953), pp. 131-40.

[11]Clarence H. Boeck, "Teaching Chemistry for Scientific Method and Attitude Development," Science Education, XXXVII (March, 1953), pp. 81-4.

Comparisons between the two groups were made on each of the following factors:

1. Knowledge of basic facts and principles of chemistry.
2. Application of the principles of chemistry to new situations.
3. Knowledge of and ability to use the scientific method with an accompanying scientific attitude.
4. Ability to perform in the laboratory with resourcefulness using sound techniques.[12]

An intelligence test, achievement examinations, and laboratory examinations were administered to the students in the study. On the basis of the statistical analysis it was concluded that students taught by the inductive-deductive method improved more than the deductive-descriptive class in: (1) scientific method and attitude development, and (2) ability to identify proper laboratory techniques. No significant differences between groups were found in relation to knowledge of chemical principles or the application of chemical principles to new situations.

Perlman[13] sought to compare three different teaching methods. One method utilized the historical case study approach, the second method applied scientific problem-solving to problems of everyday life, and the third method consisted of standard classroom demonstrations. To each of the groups was administered a battery of tests including a performance test in scientific problem-solving, a written test in scientific thinking, an intelligence test, and an achievement test. The accumulated data provided some evidence to substantiate the hypothesis that the physical science

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[12]Ibid., p. 81.

[13]James S. Perlman, "An Historical vs. Contemporary Problem Solving Use of the College Physical Science Laboratory Period for General Education," Journal of Experimental Education, XXI (March, 1953), pp. 251-7.

laboratory could be used to demonstrate the scientific approach in solving life problems without loss in subject matter achievement.

At Cornell 140 students were involved in a study conducted by Dawson[14] in which the lecture-demonstration method was compared with the problem-solving recitation method of instruction. After the classes were equated on the basis of seven factors, tests and questionnaires were utilized to collect data. From an analysis of the data Dawson found no difference between groups in the recall of specific facts, but significance was obtained in favor of problem-solving for the groups taught by the problem-solving recitation method compared with the lecture-demonstration method of instruction.

From 1948-58 Sister Marie[15] investigated the inductive and deductive methods of teaching high school chemistry. The research was carried out in two phases. Phase one involved twelve classes from three schools, three teachers and 430 chemistry students. Six classes were taught inductively, and six were taught deductively. Two standardized tests were given, the Anderson Chemistry Test and the Cooperative Chemistry Test, Form X. From a study of the data Sister Marie concluded that students in the inductive approach were better able to grasp factual chemical knowledge than those taught by the deductive method. In phase two a study involving chemical equation-balancing was conducted in fifty-six classes, and thirty-four schools.

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[14]Murray Dawson, "Lectures Versus Problem-Solving in Teaching Elementary Soil Science," Science Education, XL (December, 1956), pp. 395-404.

[15]Sister Ernestine Marie, "A Comparison of Inductive and Deductive Methods of Teaching High School Chemistry," Science Education, XLV (December, 1961), pp. 436-43.

A symbolic unit test was given (an understanding of the concepts of equation balancing was tested) to all groups. The evidence indicated that students taught inductively were better able to grasp the fundamentals of equation-balancing than students taught by the deductive-descriptive method.

Three studies of a similar nature were completed by Mark, Charen, and Montague.[16] Stephen J. Mark attempted to determine if open-ended laboratory methods would produce more favorable learning results than traditional methods. The control group performed experiments according to directions contained in the laboratory manual while the experimental group was presented with a problem and asked to devise the procedure for solving it. The results of the study provided evidence indicating that the experimental group performed significantly better in interpreting chemistry knowledge when illustrated in several graphs, tables, charts, paragraphs, and diagrams of experiments. Charen's study utilized the Manufacturing Chemists' Association's open-ended experiments. From his data Charen concluded that the majority of pupils and teachers preferred the MCA experiments over traditional laboratory materials, but that neither traditional laboratory materials or open-ended experiments proved effective in improving critical thinking in chemistry. Montague, in a third study, sought to determine the value of open-ended experiments contrasted with traditional laboratory manual experiments. He concluded

[16]Stephen J. Mark, "Experimental Study Involving the Comparison of Two Methods of Performing Experiments in H.S. Chemistry," Science Education, XLV (December, 1961), pp. 410-12; George Charen, "The Effect of Open-Ended Experiments in Chemistry on the Achievement of Certain Objectives of Science Teaching," Journal of Research in Science Teaching, I (1963), pp. 184-90; Earl J. Montague, "An Attempt to Appraise Whether Problem-Solving Abilities Can Be Developed in a General Chemistry Laboratory," The Science Teacher, XXXI (March, 1964), pp. 37-8.

on the basis of his data that: (1) the experimental group surpassed the control group in solving problems in an actual laboratory situation and on a critical thinking test; (2) no differences were found between groups in the ability to think scientifically or in achievement; and (3) the experimental group indicated a greater preference for laboratory work than did the control group.

Toohey[17] attempted to determine the effects of the lecture method compared with the laboratory method in teaching ninth grade earth science and general science. Information was gathered from test scores on the effectiveness of the two methods in promoting student achievement, retention of science information, and the ability to read and comprehend science subject matter. From this study Toohey concluded that laboratory experiences in ninth grade earth science and general science did contribute more to the retention of subject matter than the lecture-demonstration method of instruction.

Oliver[18] compared three teaching methods in high school biology, the lecture-discussion method, the lecture-discussion and demonstration method, and the lecture-discussion and demonstration method in combination with laboratory exercises. The level of accomplishment in terms of the acquisition of facts, overall achievement, and application of scientific principles in biology was measured by paper and pencil tests. Results of the study indicated that: (1) students acquired the same amount

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[17]Jack Vincent Toohey, "The Comparative Effects of Laboratory and Lecture Methods of Instruction in Earth Science and General Science Classes," (Ann Arbor, Michigan: University Microfilms, 1964).

[18]Montague Oliver, "The Efficiency of Three Methods of Teaching High School Biology," Journal of Experimental Education, XXXIII (Spring, 1965), pp. 289-300.

of factual information regardless of the method of teaching employed; and (2) high ability pupils applied scientific principles more readily than low ability pupils.

In a study at Southern Oregon College and Oregon State College Postl[19] sought to determine the contribution that observation, methods of attacking problems, and formulation of conclusions would have upon improving a student's ability to observe and reason as well as increasing his appreciation for science. Students who were enrolled in physical science courses were divided into two groups, one with laboratory instruction, and the other without laboratory instruction. Data was gathered by administering A Test of General Proficiency in the Field of Natural Sciences and A Test of Science Reasoning and Understanding Physical Sciences. The conclusion was reached that the laboratory did not contribute directly to the aims of general education as measured by the testing instruments.

Rainey[20] compared the directive with the non-directive type of laboratory instruction. The primary aim of the study was the evaluation of the effect of the non-directive method on the learning of facts and principles. Four examinations were administered in this study and from the collected data it was deduced that the type of laboratory instruction had no effect on information learning, but the non-directive laboratory

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[19]Anton Postl, "The Values of Laboratory Work in the Natural Sciences for Students of General Education," Science Education, XLIX (March, 1965), pp. 111-16.

[20]Robert G. Rainey, "The Effects of Directed versus Non-Directed Laboratory Work on High School Chemistry Achievement," Journal of Research in Science Teaching, III (1965), pp. 286-92.

group attained better results than the directive laboratory group on the laboratory performance test.

An investigation was conducted by Schefler[21] in which he compared two laboratory approaches: (1) the inductive or discovery type, and (2) the traditional lecture-demonstration type. Four classes of freshman biology studying a unit on genetics at the State University of New York College at Buffalo comprised the sample population. The four groups were pre-tested and post-tested with a battery of tests. No evidence was obtained that one type of laboratory method was superior to another, but there was some indication that teacher difference may be of greater significance than the effects of method difference.

Coulter[22] contrasted three different types of laboratory methods in ninth grade biology. The three groups were designated the inductive laboratory treatment (students devised their own experimental designs), the inductive demonstration treatment (students designed the procedure but the equipment was handled by the instructor), and the deductive laboratory treatment (students were directed in their experiments). Intelligence, scientific attitude, application of principles, reaction to teaching treatment, and critical thinking were determined by administering pre-tests and post-tests. The conclusions of the study were: (1) the inductive approach may encourage some aspects of scientific inquiry

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[21]William C. Schefler, "A Comparison Between Inductive and Illustrative Laboratories in College Biology," Journal of Research in Science Teaching, III (1965), pp. 218-23.

[22]John C. Coulter, "The Effectiveness of Inductive Laboratory, Inductive Demonstration, and Deductive Laboratory in Biology," Journal of Research in Science Teaching, IV (1966), pp. 185-6.

(cause and effect relationships, critical examination of evidence, and evaluation of arguments); and (2) no significant differences occurred between groups in knowledge of facts and principles.

In eighth grade general science a traditional group (lectures and infrequent laboratory work) was compared with an experimental group (no lectures and frequent pupil activities) by Kenneth W. Johns.[23] The two groups of students were tested for ability in problem-solving, critical thinking, study skills, subject matter achievement, and attitude toward science. No significant differences were found on any of the preceding factors.

A study to determine the advantages and disadvantages of a student-centered classroom was completed by Ledbetter.[24] The investigation was carried out with four high school chemistry classes, composed of juniors and seniors, in which the Differential Aptitude Test and the Anderson Chemistry Test were administered. Groups were matched on the basis of the Differential Aptitude Test scores while the Anderson Chemistry Test was used to compare achievement levels between groups. There was no significant difference between groups in achievement, but the author theorized that the student-centered approach promoted student participation, student responsibility, student self-evaluation, and students' realization of their needs.

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[23]Kenneth W. Johns, "A Comparison of Two Methods of Teaching Eighth Grade General Science-Traditional and Structured Problem Solving," (Ann Arbor, Michigan: University Microfilms, 1966).

[24]Elaine W. Ledbetter, "Student-Centered Teaching in High School Chemistry: An Exploratory Study," Science Education, L (March, 1966), pp. 183-6.

Sorenson[25] measured the changes that occurred in critical thinking between students in laboratory-centered and lecture-demonstration patterns of instruction. A total of twenty classes were selected, ten in the control group and ten in the experimental group. Each of the classes, which were instructed with the BSCS curriculum materials, were subsequently evaluated with five tests. Sorenson reported that: (1) the change in critical thinking and understanding of science for students in the laboratory-centered approach was significant; and (2) students in the laboratory-centered approach became less dogmatic.

Zingaro and Collette[26] compared the inductive laboratory method with the traditional laboratory method of teaching. It was hypothesized that the inductive method would increase student learning of facts and principles in college physical science, student understanding of the methods and nature of science, student ability to think critically in physical science, and student ability to think critically in non-science areas. Four tests were completed by the students which, after analysis, indicated that: (1) the type of laboratory approach did not affect the amount of subject matter learned; (2) the inductive laboratory method affected the students' ability to think critically in physical science; and (3) the effect of having or not having a certain instructor influenced student scores on the Watson-Glaser Critical Appraisal and the Test on Understanding Science.

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[25] Lavar L. Sorenson, "Change in Critical Thinking Between Students in Laboratory-Centered and Lecture-Demonstration-Centered Patterns of Instruction in High School Biology," (Ann Arbor, Michigan: University Microfilms, 1966).

[26] Joseph S. Zingaro and Alfred T. Collette, "A Statistical Comparison Between Inductive and Traditional Laboratories in College Physical Science," Journal of Research in Science Teaching, V (1967-68), pp. 269-75.

Two studies similar to those performed by Mark, Charen and Montague utilizing open-ended experiments were completed by Lennek and Murphy.[27] Lennek found that open-ended experiments did not improve students' attitudes toward science, their ability to recall information, or their performance in laboratory skills. Murphy compared a laboratory that was "content-centered" (students received specific directions) with one that was "process-centered" (students applied inductive methods to the solution of a problem). The results of the study indicated that there were no significant differences between the "content-centered" and the "process-centered" laboratory in the development of achievement, scientific attitudes, problem-solving abilities, and interest in biology.

<u>Summary of Related Literature</u>

The investigators in the preceding studies had been interested in examining numerous factors which include: (1) problem-solving, (2) achievement, (3) attitudes, (4) critical thinking, (5) understanding of science, and (6) manipulation of apparatus.

In the reported studies the investigators have been nearly unanimous in stating that most teaching methods have been equally effective in student acquisition of factual information. One exception, however, is the lecture-demonstration method which has generally been shown to be superior to other methods in the immediate recall of factual information. In addition, the laboratory method of instruction has been proven, in the majority of cases, to be effectual in the delayed recall of information.

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[27]David Lennek, "Open-Ended Experiments in Junior High School Science-A Study of Their Effect on the Acquisition of Science Information, Laboratory Skills, and Attitudes Towards Science," (Ann Arbor, Michigan: University Microfilms, 1968); Glenn W. Murphy, "Content Versus Process-Centered Biology Laboratories, Part II: The Development of Knowledge, Scientific Attitudes, Problem-Solving Ability and Interest in Biology," <u>Science Education</u>, LII (March, 1968), pp. 148-62.

Many of the studies in which an investigation was made concerning attitude development have provided results which indicated a tendency in favor of the problem-solving method of instruction. In one instance, Boeck concluded that the inductive-deductive method was superior to the deductive-descriptive method of instruction in the development of scientific attitudes. In contrast, Lennek concluded that open-ended experiments did not improve students' scientific attitudes.

When problem-solving proficiency was investigated in a particular subject, results of the studies were frequently interpreted as being in favor of laboratory work that encouraged inquiry as exemplified by open-ended or inductive laboratory activities. In addition, those studies that involved generalized problem-solving ability usually revealed no significant results in relation to the teaching method employed.

The measurement of student understanding of science is an area of continuing confusion, and no convincing results have been reported in favor of any particular teaching method. This is probably due to the fact that it is extremely difficult to find a suitable evaluation instrument to measure a student's understanding of science. Both Sorenson and Boeck, however, found that the improvement in the understanding of science was significant for those students in a laboratory-centered approach.

One factor (laboratory manipulation of equipment), reported by many investigators, indicated that laboratory work increased student familiarity with and ability to handle apparatus. Also, it is interesting to note that Collette, Schefler, and Zingaro have indicated that teacher difference may be of greater consequence than method difference.

All of the studies that have been reviewed betoken a concern for determining the value of scientific laboratory work. Recently, there has been an increasing desire to evaluate the relationship between laboratory work and less tangible factors such as attitude development in science, understanding of science, and problem-solving. No research studies were located which related certain student behaviors in the laboratory with an increased understanding of science, an understanding of the methods and aims of science, and an improved attitude toward science.

CHAPTER III

PROCEDURE

Introduction

It is evident from past studies that the educational value of the scientific laboratory has not been demonstrated. Previous studies involving the science laboratory have largely been concerned with comparisons between the lecture-demonstration approach and the laboratory approach in which indications of significant differences in factual achievement level have been sought. As a general rule, the data gleaned from these experiments have indicated a preference for the chemistry class without laboratory as contrasted with those classes that did have a laboratory. Since the results of the aforementioned studies were largely based upon the limited goal of student achievement of factual knowledge, it would seem logical to consider other possible outcomes of laboratory instruction. In view of this, the need existed for a study in which an investigation would be made to determine the behaviors of students in the chemistry laboratory that contribute to an understanding of science, an understanding of the methods and aims of science, and an improved attitude toward science.

Development of the Criteria

During January and February, 1969, a survey of the scientific literature was conducted concerning student laboratory behaviors which might contribute to a student's understanding of science, an understanding of the methods and aims of science, and to an improvement of student attitudes toward science. From this survey, which included the writings of selected scientists and science educators since 1900, statements relating to an understanding of science, an understanding of the methods and aims of science, and an improved attitude toward science were noted for future study. Initially, there were eighty-two statements, obtained from at least 200 books and articles (selected list in Appendix A). Duplications of statements were omitted, and from the original list forty-two statements were retained. The forty-two statements were then subdivided into two lists, one list written in terms of teacher behaviors, and the other list written in terms of student behaviors in the laboratory. Now of the two kinds of behavior, student behavior, rather than teacher behavior, is most likely to be indicative of student beliefs, mores, and values. For this reason, student behaviors were chosen as the key to this project, and all statements referring to teacher behavior were omitted from the list. It further seemed logical that evidence of student understanding of science, understanding of the methods and aims of science, and improved attitudes toward science could best be observed while the students were engaged in laboratory work. Jay Young has stated that: "It seems to me that it is practical to look for this evidence as we observe the student at his lab bench, as we discuss his ideas with him, and as we examine his real laboratory report."[1]

The investigator and his associate[2] observed the behavioral

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[1]Jay A. Young, "What Should Students Do in the Laboratory?", Journal of Chemical Education, XLV (December, 1968), p. 800.

[2]Marvin Kendall, who completed a project similar to this one in physics, was the investigator's associate.

practices of high school chemistry students in an actual high school chemistry laboratory environment in order to determine the feasibility of using the investigator's list of twenty-three student behavioral practices in an observational instrument. After observing the behavioral practices of students in a laboratory, five behavioral practices were eliminated from the list as a result of difficulty in observation. The five items eliminated appear in Appendix B. This left a total of eighteen behavioral practices for evaluative purposes (See Appendix C for the complete list of behavioral practices). Four examples of the behavioral practices as they appear in the evaluative instrument are:

1. The student contributes to the procedure in solving a laboratory problem.
2. The student constructs graphs and interprets them.
3. The student analyzes and interprets data.
4. The student designs equipment.

Three classifications were used in the evaluative instrument to evaluate each one of the student behaviors. One category was "yes" (behavior was practiced by students in laboratory), the second was "no" (behavior was not practiced by students in laboratory), and the third was "unobserved" (behavior was not called for by the laboratory problem during the period of observation). The number of students in each laboratory class exhibiting each behavioral practice was recorded on the evaluative instrument. Then this number was expressed as a ratio of the class, which in turn was converted into a percentage. A quartile percentage was arbitrarily chosen for each behavioral practice, and, if the class percentage met or exceeded the predetermined percentage, it was checked as "yes".

Description and Selection of the High School Chemistry Classes

The eleven high school chemistry classes that participated in this study had a total population of 276 students. The total population of the classes was almost equally divided between males and females, but students with junior class standing far outnumbered those with senior class standing. The schools, from which the classes were chosen, were located in Massachusetts and New Hampshire. The classes were selected because it was the opinion of the investigator and his associate that the classes represented two ends of a continuum. One end of this continuum represented schools with chemistry classes in which students were encouraged to engage in many of the behavioral practices, while the other end of the continuum represented schools with chemistry classes in which the opposite was true. Selection of the classes was based on the recommendations of a science educator, secondary school science teachers, and the investigator and his associate. One high school chemistry laboratory class originally contacted for inclusion in this study was eliminated, since school committee policy did not permit the investigator to observe classes or administer tests to students.

The schools selected for the study cooperated with the investigator in the following ways: (1) the teacher permitted the observation of actual chemistry laboratory activities; (2) the teacher permitted the administration of TOUS and VAS during regularly scheduled class periods; and (3) the teacher discussed such information as the nature of the classroom environment (i.e. the teaching method employed, the textbook used, and the qualifications of the classroom teacher).

Research Procedure and Design

During the period from March to May, 1969, using the behavioral practices as an observational instrument (see Appendix C), overtly observed laboratory behavior was evaluated by the investigator and his associate. A minimum of 120 minutes and a maximum of 200 minutes were spent in observing laboratory periods in each school, and additional time was spent if classroom observations were included. Differences in length of observations occurred, since the observers spent more time in reaching agreement on their evaluation in some of the classes in relation to others, and laboratory periods varied in length of time due to dissimilarities in school scheduling and teacher planning. Next each observer, using the checklist of behavioral practices, recorded the number of students in each laboratory class exhibiting each behavioral practice. Then this number was expressed as a ratio of the class which in turn was converted into a percentage. A quartile percentage was arbitrarily chosen for each behavioral practice, and, if the class percentage met or exceeded the predetermined percentage, it was checked as "yes". The two lists were then compared to determine if conformity in rating existed between the two observers. If discrepencies did exist in the way a behavioral practice had been rated, further observations were made of the chemistry class in question until complete agreement was reached by the observers on the item or items in question. This procedure resulted in a final inventory of behavioral practices for each classroom which represented a composite evaluation made by the two investigators.

TOUS and VAS were administered to high school chemistry classes during April and May, 1969. All tests were given under the supervision of either the investigator or his associate, thus assuring a uniform testing environment. Every student was supplied with a test booklet, an answer sheet, and a pencil to use in recording his answers. Each class was told that the tests would not contribute toward their class grade. The examiners read the directions to the students for both tests, and guided the students in responding to the sample question on the test booklet. The students were allowed exactly forty minutes uninterrupted working time for TOUS. Scoring for TOUS was done by determining the number of correct responses. For the purpose of this study, the total score for TOUS plus a subscore for Part III of TOUS were obtained. In the case of VAS, the final forty-item scale, comprised of twenty positive statements and twenty negative statements, was scrambled by using a table of random numbers.

No time limit was placed upon the students' responding to questions on VAS. Students were directed to indicate the extent of their support or disagreement on each statement by rating the statement either positive 1, 2, or 3, or negative 1, 2, or 3. The answer sheets were hand scored with two separate answer keys; one key was used to score the negative items, and the second key was used to score the positive items.

The units of analysis for each of the behavioral practices listed in Appendix C were the mean average scores which the classes achieved on each test and Part III of TOUS. The statistical technique was a one-way analysis of variance F-test, and a statistically significant difference in the means resulted in the rejection of the null hypothesis. In turn, rejection of the null hypothesis would be interpreted as meaning that the particular observed laboratory behavior tested had contributed to either an understanding of science, as measured by TOUS, or an improved attitude toward science, as measured by VAS, or an understanding of the methods and aims of science, as measured by Part III of TOUS. A complete description of this statistical method can be found in Myer's Fundamentals of Experimental Design.

Description of the Instruments

Test on Understanding Science[3] (hereafter referred to as TOUS).--TOUS has been reported by Cooley and Klopfer as having value in measuring student understanding of science. "Turning to the possible applications of TOUS in curriculum developments the most obvious use of this instrument is in the direct testing of high school students to determine to what extent a realistic understanding of science and scientists has been attained as a result of taking science courses."[4] Watson further stated that this test should be used to measure other outcomes of the science course besides factual achievement:

> So long as pupil accomplishment and, inevitably, teacher success are defined in terms of narrowly conceived achievement examinations, teachers will center their explicit instructional purposes around the limited

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[3]This section is based upon the following sources: William W. Cooley and Leopold E. Klopfer, Test on Understanding Science (Cambridge, Massachusetts: Harvard University Press, 1961); "The History of Science Cases for High Schools in the Development of Student Understanding of Science and Scientists," A Report on the HOSC Instruction Project, Journal of Research in Science Teaching, I (1963), pp. 33-47; "The Evaluation of Specific Educational Innovations," Journal of Research in Science Teaching, I (1963), pp. 73-80.

[4]Cooley and Klopfer, Test on Understanding Science, p. 9.

kinds of tasks required in these examinations. Or conversely, they will not be willing to invest much effort in other types of objectives. For this reason, such instruments as the Test of Knowledge About Science and Scientists and the Test on Understanding Science should be used to probe further into the affective domain.[5]

Eighteen themes were identified by the authors of TOUS as being important for an understanding of science and scientists. These eighteen themes were divided into three major areas with seven themes enumerated in Area I, three themes in Area II, and eight themes in Area III. The three areas and eighteen themes are as follows:

Area I - The Scientific Enterprise
- Theme 1. Human element in science.
- 2. Communication among scientists.
- 3. Scientific societies.
- 4. Instruments.
- 5. Money.
- 6. International character of science.
- 7. Interaction of science and society.

Area II - The Scientist.
- Theme 1. Generalizations about scientists as people.
- 2. Institutional pressures on scientists.
- 3. Abilities needed by scientists.

Area III - Methods and Aims of Science.
- Theme 1. Generalities about scientific methods.
- 2. Tactics and strategy of sciencing.
- 3. Theories and models.
- 4. Aims of science.
- 5. Accumulation and falsification.
- 6. Controversies in science.
- 7. Science and technology.
- 8. Unity and interdependence of the sciences.[6]

Cooley and Klopfer developed a test to measure the aforementioned understandings by choosing 60 multiple-choice items from a pool of 200

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[5]Fletcher G. Watson, "Research on Teaching Science," in Handbook of Research on Teaching, ed. by N.L. Gage (Chicago: Rand, McNally & Company), p. 1034.

[6]Cooley and Klopfer, Test on Understanding Science, pp. 3-4.

multiple-choice items that had been submitted for their review. These 60 items constituted Form X of TOUS and a total of 18 test items evaluated Area I, 18 test items evaluated Area II, and 24 test items evaluated Area III.

Form W of TOUS was validated by administering Form X (identical to Form W with minor revisions) to approximately 3,000 students in 108 high schools in October, 1960, and again in March, 1961. An analysis of specific items was carried out utilizing McNemar's Chi Square Test of change in order to determine the effectiveness of each item. The reliability of the test was reported as .76 and an indication of external validity was demonstrated by the following:

> TOUS was administered twice, once at the beginning of July and again at the end of August, 1960 to 78 talented high school students in two summer programs, the students were in active contact with working scientists. The observed significant changes in their responses to items on TOUS toward the desired "correct" responses at the end of their summer science experience gives some indication of the validity of the test. A similar group of students who were not participating in such special summer science programs did not tend to move toward the correct responses.[7]

Form W of the test consisted of 60 items with four alternative answers in the multiple-choice design. The test items and the directions were included in booklet form with student responses recorded on a separate IBM answer sheet. Suggested working time was forty minutes.

Vitrogan Attitude Scale[8] (hereafter referred to as VAS).--Vitrogan has stated that the learning process in science is as important

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[7]Ibid., pp. 6-7.

[8]This section is based upon the following sources: David Vitrogan, "Characteristics of a Generalized Attitude Toward Science," School Science and Mathematics, LXIX (February, 1969), pp. 150-58; "A Method for Determining a Generalized Attitude Toward Science," and "Origins of the Criteria of a Generalized Attitude Toward Science," Science Education, LI (March, 1967), pp. 170-74, 175-86.

as the factual information acquired. "Thus the processes of science, which have been the concern of the scientist who has contributed creatively toward our knowledge of science, have only recently become the concern of the science educator."[9] Vitrogan is convinced that attitudes play a role in an individual's behavior and in his ability to utilize the processes of science. Thus, VAS was developed to measure the components of a generalized attitude toward science.

Vitrogan based the criteria that formed the Vitrogan Attitude Scale on the writings of such authors as John Dewey, Karl Pearson, Wendell Johnson, Morris R. Cohen, Ernest Nagel, Bertrand Russell, Fritz Kohn, J.J. Schwab, and others. The criteria, derived by Vitrogan, for a positive generalized attitude toward science are characterized by the following eight factors:

> (1) a predisposition to discern the degree in which one person or thing differs from another; a tendency to emphasize differences
> (2) a tendency to challenge authority, to test traditional beliefs and customs with actual observation and experience.
> (3) a readiness to change as changing conditions require; a multiple and flexible approach to people and things
> (4) an ability to differentiate between controlled and reliable observation as opposed to casual observation
> (5) a basic notion that reality is to be regarded as a process implying continuous change; no two things are exactly alike, no one thing stays the same
> (6) structure in the form of relations and equations will be stressed over function; structure, the nature of the phenomenon, the broad unifying principle is stressed rather than application (detail) or function.
> (7) greater concern for research rather than findings; greater emphasis on the inquiring, the questionning rather than the final answers obtained; the form of the question is considered more important than the answer observed
> (8) an emphasis on probability type explanations rather than absolute solutions.[10]

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[9]Vitrogan, "Characteristics of a Generalized Attitude Toward Science," p. 150.

[10]Ibid., p. 151.

The criteria for a negative generalized attitude toward science would be characterized by these factors:

(1) a tendency to emphasize similarities and overlook and minimize differences; a predisposition to expect different things to be the same
(2) a predisposition to accept authority and suggestion
(3) a tendency to maintain established beliefs regardless of changing conditions; a singular and rigid approach to people and things
(4) an inability to distinguish between casual and controlled observation
(5) a static orientation where reality is viewed as having an unchanging character, a stability and constancy
(6) emphasis of the relations in the form of equations; experimental design and logic are minimized; function, utility and application are stressed
(7) a preference for final answers obtained from basic questions minimizing the methods used in inquiring; the answer is considered more important
(8) an acceptance of absolute solutions.[11]

In the process of developing his attitude scale, Vitrogan identified two groups of students ranging in age from thirteen to fifteen years. They were enrolled in the sophomore year of high school and had completed courses in general science and biology. One group had demonstrated a high motivational involvement with the objects and ideas associated with science, possessed a high degree of educational development in science, obtained high achievement in science courses, and had a high interest in science. The other group had demonstrated a low interest, low achievement, low educational development, and little motivational involvement in science. The criterion measures used to evaluate these factors included the <u>Kuder Preference Form - Vocational Interest Test</u>, the <u>Iowa Test of Educational Development</u>, average school marks in general science and

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[11]Ibid.

biology, and a science teacher's rating scale. The sample population was composed of students who scored either in the upper quarter or lower quarter on all four criterion measures.

A questionnaire developed by Vitrogan and indicating the hypothetical components of a generalized attitude toward science was administered to both groups. The results of the questionnaire allowed Vitrogan to identify four of the hypothetical components from his list of eight. Since these two groups, representing different ends of the spectrum, exhibited differences on four of the proposed attitude components, the author incorporated these four areas into an attitude scale consisting of eighty items. This attitude scale was written in the language used by the subjects with statements written in such a way as to allow the individual to express either a positive attitude or negative attitude toward science.

The attitude scale was then administered to a second population of 205 students. Based upon the four criterion measures used to identify students who were highly motivated and interested in science in contrast with those who were not highly motivated and interested in science, this eighty-item scale statistically measured a difference significant at the .01 level.

Internal consistency was checked by means of an item analysis, and a Bi-serial coefficient of correlation was used to determine the discriminatory power of each item. The forty most discrminatory items were ultimately used in the final form of the attitude toward science scale. Using the Spearman-Brown formula, the reliability of the instrument was estimated at 0.88. Vitrogan stated that this attitude scale would differentiate between students who demonstrated either a high or a low motivational involvement in science. He recommended that his attitude scale be used for research in which an attempt would be made to relate current practices in the science classroom with the development of the components of a positive generalized attitude toward science.

CHAPTER IV

TREATMENT AND ANALYSIS OF THE DATA

Introduction

One of the purposes of this study was to determine those behavioral practices that might contribute to a student's understanding of science, understanding of the methods and aims of science, and an improved attitude toward science. Hence, a survey of the scientific literature was conducted concerning student laboratory behaviors in science. From this survey, which included the writings of selected scientists and science educators since 1900, a list of behavioral practices was delineated by the investigator and an associate. The investigator and an associate then observed the behavioral practices of high school chemistry students in an actual high school chemistry laboratory environment in order to determine the feasibility of using the behavioral practices in an observational instrument. Subsequently, the relevant behavioral practices were included in an observational instrument which was used by the two observers to rate high school chemistry laboratories. Following the observation of students in eleven chemistry classrooms, each behavioral practice was included in a null hypothesis, and the hypothesis was then tested with a one-way analysis of variance for unequal cell sizes. A model for the analysis of variance test is given on page 75 of

Myer's Fundamentals of Experimental Design.

The data for each analysis of variance test was obtained by administering TOUS and VAS to the students in eleven chemistry classes. Class means on VAS, TOUS, and Part III of TOUS were utilized as the basic units of analysis. In addition to the total score for TOUS, a separate score was obtained on Part III of TOUS (understandings about the methods and aims of science), since it was felt by the investigator that the observed behavioral practices should make a unique contribution to this part of the test. The use of any of the subscores obtained from TOUS (TOUS consists of three subscores and a final score) has been recommended for certain evaluative purposes by the authors of the test.

In preparing the mean scores for analysis, the classes were divided into two groups according to whether the classes did or did not practice each behavior. The computations were completed for each analysis of variance with the use of the computer at the University of Massachusetts.

Information is presented on class size, range of scores, class means, and standard deviations in Tables B (results on VAS), C (results on TOUS), and D (results on Part III of TOUS). Tables B_1----B_{18} show the analysis of variance results, using the test data from VAS, for each behavioral practice; Tables C_1-----C_{18} show the analysis of variance results, using the test data from TOUS, for each behavioral practice; and Tables D_1-----D_{18} show the analysis of variance results, using the test data from Part III of TOUS, for each behavioral practice.

The tables display the means utilized in obtaining the results for each analysis of variance. A summary of the significance of each behavioral practice has been included at the end of each section of tested hypotheses.

TABLE B

CLASS NUMBER, CLASS SIZE, RANGE, CLASS MEAN AND STANDARD DEVIATION FOR VAS

Class Number	Class Size	Range	Class Mean	Standard Deviation
1	40	-5 to 62	24.90	17.51
2	37	-4 to 60	25.95	16.80
3	30	-48 to 58	11.80	23.59
4	28	-35 to 61	21.50	20.91
5	25	-10 to 78	28.00	20.02
6	25	-20 to 71	19.20	22.68
7	23	-47 to 81	23.52	27.19
8	18	-33 to 61	21.78	24.32
9	17	-4 to 64	28.82	16.30
10	16	-3 to 67	31.94	18.03
11	12	-29 to 65	14.75	22.77

TABLE C

CLASS NUMBER, RANGE, CLASS SIZE, CLASS MEAN, AND STANDARD DEVIATION FOR TOUS

Class Number	Class Size	Range	Class Mean	Standard Deviation
1	40	32-41	30.45	5.24
2	39	17-47	36.36	6.88
3	30	20-46	31.53	5.57
4	28	20-44	35.36	5.95
5	26	24-48	34.88	6.02
6	25	14-52	31.64	8.59
7	23	25-51	38.35	6.31
8	18	24-45	33.89	5.20
9	17	23-47	33.12	7.08
10	17	22-41	33.82	5.07
11	13	24-40	33.00	4.83

TABLE D

CLASS NUMBER, CLASS SIZE, RANGE, MEAN, AND STANDARD DEVIATION FOR PART III OF TOUS

Class Number	Class Size	Range	Class Mean	Standard Deviation
1	40	5-16	10.30	2.71
2	39	7-19	12.82	3.18
3	30	4-14	10.73	2.41
4	28	8-16	12.25	2.29
5	26	6-18	12.69	2.99
6	25	4-22	11.84	4.36
7	23	6-19	14.04	3.13
8	18	6-18	11.11	3.25
9	17	8-17	12.76	2.44
10	17	6-15	11.88	2.47
11	13	8-14	11.54	2.03

TABLE B_1

Behavioral practice 1 - The student contributes to the procedure in solving a laboratory problem.

Null hypothesis B_1 - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 1 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	21.78	31.94	25.95	24.90	21.50
Group 2	No	11.80 23.52	14.75	23.82	28.00	19.20

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	25.214	20.182
Standard Deviation	4.227	6.103

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	69.0665	1	69.0665	2.4122
Within Groups	257.6928	9	28.6325	
Total	326.7593	10		

Not significant.

*Significance at ($p < .05$) requires $F\ (1,9) > 5.12$.

TABLE B_2

Behavioral practice 2 - The student constructs graphs and interprets them.

Null hypothesis B_2- There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 2 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.80	21.78	31.94	25.95	24.90
		19.20	21.50			
Group 2	No	14.75	23.82	23.55		

Treatment Group	1	2
Sample Size	7	3
Mean (Group)	22.439	20.697
Standard Deviation	6.240	5.152

Analysis of Variance

	Sum of Squares	DF	Mean Square	R Ratio
Between Groups	6.3719	1	6.3719	0.1778
Within Groups	286.7374	8	35.8422	
Total	293.1092	9		

Not significant.

*Significance at ($p < .05$) requires $F\ (1,8) > 5.32$.

TABLE B_3

Behavioral practice 3 - The student analyzes and interprets data.

Null hypothesis B_3 - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 3 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.80	14.75	21.78	31.94	25.95
		28.00	24.90	21.50	23.52	
Group 2	No	23.82	19.20			

Treatment Group	1	2
Sample Size	9	2
Mean (Group)	22.682	21.510
Standard Deviation	6.263	3.267

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	2.2485	1	2.2485	0.0624
Within Groups	324.5108	9	36.0568	
Total	326.7593	10		

Not significant.

*Significance at $(p < .05)$ requires $F(1,9) > 5.12$.

TABLE B_4

<u>Behavioral practice 4</u> - The student designs equipment.

<u>Null hypothesis B_4</u> - There is no significant difference in attitudes toward science, as measured by <u>VAS</u>, between groups of students who exhibit the behavior specified in behavioral practice 4 and those groups of students who do not exhibit the behavior.

<u>Group Means</u>

Group 1	Yes	31.94				
Group 2	No	11.80	14.75	21.78	23.82	25.95
		28.00	24.90	19.20	21.50	23.52

Treatment Group	1	2
Sample Size	1	10
Mean (Group)	31.940	21.522
Standard Deviation	0.000	5.034

<u>Analysis of Variance</u>

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	98.6679	1	98.6679	3.8932
Within Groups	228.0914	9	25.3435	
Total	326.7593	10		

Not significant.

*Significance at ($p < .05$) requires $F\ (1,9) > 5.12$.

TABLE B_5

Behavioral practice 5 - The student establishes the limitations of the experimental conclusions.

Null hypothesis B_5 - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 5 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	21.78	31.94	24.90		
Group 2	No	11.80	14.75	23.82	25.95	28.00
		19.20	21.50	23.52		

Treatment Group	1	2
Sample Size	3	8
Mean (Group)	26.207	21.067
Standard Deviation	5.205	5.542

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	57.6241	1	57.6241	1.9270
Within Groups	269.1352	9	29.9039	
Total	326.7593	10		

Not significant.

*Significance at ($p < .05$) requires $F_{(1,9)} > 5.12$.

TABLE B_6

Behavioral practice 6 - The student uses unassigned reference material (excluding textbook).

Null hypothesis B_6 - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 6 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	31.94	25.95	24.90	21.50	23.52
Group 2	No	11.80 19.20.	14.75	21.78	23.82	28.00

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	25.562	19.892
Standard Deviation	3.035	5.952

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	87.6891	1	87.6891	3.3011
Within Groups	239.0702	9	26.5634	
Total	326.7593	10		

Not significant.

*Significance at ($p<.05$) requires F (1,°)$\geq$5.12.

TABLE B_7

Behavioral practice 7 - The student develops ways of testing his proposed conclusions.

Null hypothesis B_7 - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 7 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	21.78	31.94	25.95	24.90	21.50
Group 2	No	11.80 23.52	14.75	23.82	28.00	19.20

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	25.214	20.182
Standard Deviation	4.227	6.103

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	69.0665	1	69.0665	2.4122
Within Groups	257.6928	9	28.6325	
Total	326.7593	10		

Not significant.

*Significance at $(p < .05)$ requires $F\ (1,9) > 5.12$.

TABLE B_8

Behavioral practice 8 - The student constructs conceptual models.

Null hypothesis B_8 - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 8 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	21.78	28.00	24.90	19.20	21.50
Group 2	No	11.80 23.52	14.75	31.94	23.82	25.95

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	23.076	21.963
Standard Deviation	3.419	7.438

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	3.3764	1	3.3764	0.0940
Within Groups	323.3829	9	35.9314	
Total	326.7593	10		

Not significant.

*Significance at ($p < .05$) requires $F(1,9) > 5.12$.

TABLE B_9

Behavioral practice 9 - The student criticizes his results.

Null hypothesis B_9 - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 9 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	14.75	21.78	31.04	25.95	28.00
		24.90	21.50	23.52		
Group 2	No	11.80	23.82	19.20		

Treatment Group	1	2
Sample Size	8	3
Mean (Group)	24.042	18.273
Standard Deviation	5.080	6.063

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	72.6181	1	72.6181	2.5717
Within Groups	254.1412	9	28.2379	
Total	326.7593	10		

Not significant.

*Significance at $(p < .05)$ requires $F\ (1,9) > 5.12$.

TABLE B_{10}

Behavioral practice 10 - The student relates principles from one subject area to another.

Null hypothesis B_{10} - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 10 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	21.78	25.95	28.00	23.52	
Group 2	No	11.80 23.82	14.75	31.99	19.20	21.50

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	24.812	20.502
Standard Deviation	2.728	7.118

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	44.5999	1	44.5999	1.2943
Within Groups	275.6592	8	34.4574	
Total	320.2590	9		

Not significant.

*Significance at ($p < .05$) requires $F(1,8) > 5.32$.

TABLE B_{11}

Behavioral practice 11 - The student selects the mathematical operations to be performed on quantitative information.

Null hypothesis B_{11} - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 11 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	21.78 21.50	31.94	25.95	24.90	19.20
Group 2	No	11.80	14.75	28.00	23.52	

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	24.212	19.518
Standard Deviation	4.508	7.534

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	52.8845	1	52.8845	1.5562
Within Groups	271.8674	8	33.°834	
Total	324.7518	9		

Not significant.

*Significance at ($p < .05$) requires $F(1,8) > 5.32$.

TABLE B_{12}

Behavioral practice 12 - The student writes an essay report.

Null hypothesis B_{12} - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 12 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.80	23.82	28.00	24.90	21.50
Group 2	No	14.75 23.52	21.78	31.94	25.95	19.20

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	22.004	22.857
Standard Deviation	6.165	5.878

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	1.9828	1	1.9829	0.0549
Within Groups	324.7765	9	36.0863	
Total	326.7593	10		

Not significant.

*Significance at ($p < .05$) requires $F\ (1,9) > 5.12$.

TABLE B_{13}

Behavioral practice 13 - The student observes and records accurately.

Null hypothesis B_{13} - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 13 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	14.75	21.78	31.94	25.95	28.00
		24.90	19.20	21.50	23.52	
Group 2	No	11.80	23.82			

Treatment Group	1	2
Sample Size	9	2
Mean (Group)	23.504	17.810
Standard Deviation	5.018	8.499

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	53.0619	1	53.0619	1.7448
Within Groups	273.6974	9	30.4108	
Total	326.7593	10		

Not significant.

*Significance at ($p < .05$) requires $F(1,9) > 5.12$.

TABLE B_{14}

Behavioral practice 14 - The student realizes the limitations of the instrument he is using.

Null hypothesis B_{14} - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 14 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	25.95	24.90	21.50	23.52	19.20
Group 2	No	11.80	14.75	31.94	28.00	

Treatment Group	1	2
Sample Size	5	4
Mean (Group)	23.014	21.622
Standard Deviation	2.705	9.846

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	4.3028	1	4.3028	0.0941
Within Groups	320.1080	7	45.7297	
Total	324.4108	8		

Not significant.

*Significance at ($p < .05$) requires $F\ (1,7) > 5.59$.

TABLE B_{15}

Behavioral practice 15 - The student re-evaluates his ideas and opinions.

Null hypothesis B_{15} - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 15 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	14.75	21.78	25.95	28.00	24.90
		21.50	23.52			
Group 2	No	31.94	19.20	23.82		

Treatment Group	1	2
Sample Size	7	3
Mean (Group)	22.914	24.987
Standard Deviation	4.269	6.450

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	9.0190	1	9.0190	0.3748
Within Groups	192.5278	8	24.0660	
Total	201.5468	9		

Not significant.

*Significance at ($p < .05$) requires $F(1,8) > 5.32$.

TABLE B_{16}

Behavioral practice 16 - The student suspends judgment on experimental outcomes until the data have been analyzed.

Null hypothesis B_{16} - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 16 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.80	21.78	31.94	25.95	28.00
		24.90	21.50			
Group 2	No	23.82	23.52			

Treatment Group	1	2
Sample Size	7	2
Mean (Group)	23.696	23.670
Standard Deviation	6.364	0.212

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between groups	0.0010	1	0.0010	0.0000
Within groups	243.0714	7	34.7245	
Total	243.0724	8		

Not significant.

*Significance at ($p < .05$) requires $F\ (1,7) > 5.59$.

TABLE B_{17}

Behavioral practice 17 - The student proposes additional problems as a result of laboratory activities.

Null hypothesis B_{17} - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 17 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	31.94	24.90			
Group 2	No	11.80	14.75	21.78	23.82	25.95
		28.00	19.20	21.50	23.52.	

Treatment Group	1	2
Sample Size	2	9
Mean (Group)	28.420	21.147
Standard Deviation	4.978	5.189

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between groups	86.5659	1	86.5659	3.2436
Within groups	240.1934	9	26.6882	
Total	326.7593	10		

Not significant.

*Significance at $(p<.05)$ requires $F(1,9)>5.12$.

TABLE B_{18}

Behavioral practice 18 - The student works on different laboratory problems at the same time.

Null hypothesis B_{18} - There is no significant difference in attitudes toward science, as measured by VAS, between groups of students who exhibit the behavior specified in behavioral practice 18 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	21.78 23.52	31.94	25.95	24.90	21.50
Group 2	No	11.80	14.75	23.82	28.00	19.20

Treatment Group	1	2
Sample Size	6	5
Mean (Group)	24.932	19.514
Standard Deviation	3.843	6.574

Analysis of Variance

	Sum of Squares	DF	Mean Squares	F Ratio
Between groups	80.0485	1	80.0485	2.9202
Within groups	246.7108	9	27.4123	
Total	326.7593	10		

Not significant.

*Significance at ($p < .05$) requires $F(1,9) > 5.12$.

Summary for the Analysis of Scores on VAS

As a result of the analysis of the data on VAS, for behavioral practices 1 through 18, the null hypotheses were accepted. The investigator concluded that the listed eighteen behavioral practices did not contribute to an improved attitude toward science, as measured by VAS. Behavioral practices 4, 6, and 17 show a trend toward significance in favor of the classes in which those behaviors are practiced which may indicate the possibility that a student should design his own equipment, use unassigned reference materials, and propose additional problems as a result of his laboratory work. On the other hand, an improved attitude toward science was not indicated by the analysis to be the result of the following behavioral practices: (1) the student contributes to the procedure in solving a laboratory problem; (2) the student constructs graphs and interprets them; (3) the student analyzes and interprets data; (5) the student establishes the limitations of the experimental conclusions; (7) the student develops ways of testing his proposed conclusions; (8) the student constructs conceptual models; (9) the student criticizes his results; (10) the student relates principles from one subject area to another; (11) the student selects the mathematical operations to be performed on quantitative information; (12) the student writes an essay report; (13) the student observes and records accurately; (14) the student realizes the limitations of the instrument he is using; (15) the student re-evaluates his ideas and opinions; (16) the student suspends judgment on experimental outcomes until the data have been analyzed; and (18) the students work on different laboratory problems at the same time.

The results obtained from the analysis of the data depend upon the investigator's observation and the sensitivity of VAS in measuring student attitudes toward science. In spite of the fact that VAS was developed for high school students, it may not be sensitive enough to detect differences between various sized groups of science students.

TABLE C_1

Behavioral practice 1 - The student contributes to the procedure in solving a laboratory problem.

Null hypothesis C_1 - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 1 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	33.89	33.82	36.36	30.45	35.36
Group 2	No	31.53 38.35	33.00	33.12	34.88	31.64

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	33.976	33.753
Standard Deviation	2.240	2.560

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.1352	1	0.1352	0.0230
Within Groups	52.8401	9	5.8711	
Total	52.9753	10		

Not significant.

*Significance at ($p < .05$) requires $F\ (1,9) > 5.12$.

TABLE C_2

Behavioral practice 2 - The student constructs graphs and interprets them.

Null hypothesis C_2 - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 2 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	31.53 35.36	33.89 31.64	33.82	36.36	30.45
Group 2	No	33.00	33.12	38.35		

Treatment Group	1	2
Sample Size	7	3
Mean (Group)	33.293	34.823
Standard Deviation	2.169	3.055

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	4.9190	1	4.9190	0.8391
Within Groups	46.8996	8	5.8625	
Total	51.8186	9		

Not significant.

*Significance at ($p < .05$) requires $F(1,8) > 5.32$.

TABLE C_3

Behavioral practice 3 - The student analyzes and interprets data.

Null hypothesis C_3 - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 3 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	31.53	33.00	33.89	38.82	36.36
		34.88	30.45	35.36	38.35	
Group 2	No	33.12	31.64			

Treatment Group	1	2
Sample Size	9	2
Mean (Group)	34.182	32.380
Standard Deviation	2.413	1.047

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	5.3149	1	5.3149	1.0036
Within Groups	47.6604	9	5.2956	
Total	52.9753	10		

Not significant.

*Significance at ($p < .05$) requires $F(1,9) > 5.32$.

TABLE C_4

Behavioral practice 4 - The student designs equipment.

Null hypothesis C_4 - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 4 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	33.82				
Group 2	No	31.53	33.00	33.89	33.12	36.36
		34.88	30.45	31.64	35.36	38.35

Treatment Group	1	2
Sample Size	1	10
Mean (Group)	33.820	33.858
Standard Deviation	0.000	2.426

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.0013	1	0.0013	0.0002
Within Groups	52.9740	9	5.8860	
Total	52.9753	10		

Not significant.

*Significance at ($p < .05$) requires $F(1,9) > 5.12$.

TABLE C_5

Behavioral practice 5 - The student establishes the limitations of the experimental conclusions.

Null hypothesis C_5 - Thereis no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 5 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	33.89	33.82	30.45		
Group 2	No	31.53	33.00	33.12	36.36	34.88
		31.64	35.36	38.35		

Treatment Group	1	2
Sample Size	3	8
Mean (Group)	32.720	34.280
Standard Deviation	1.966	2.388

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	5.3097	1	5.3097	1.0025
Within Groups	47.6656	9	5.2962	
Total	52.9753	10		

Not significant.

*Significanceat ($p < .05$) requires $F(1,9) > 5.12$.

TABLE C_6

Behavioral practice 6 - The student uses unassigned reference material (excluding textbook).

Null hypothesis C_6 - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 6 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	33.82	36.36	30.45	35.36	38.35
Group 2	No	31.53 31.64	33.00	33.89	33.12	34.88

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	34.868	33.010
Standard Deviation	2.967	1.292

Analysis of Variance

[illegible]	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	9.4150	1	9.4150	1.9452
Within Groups	43.5603	9	4.8400	
Total	52.9753	10		

Not significant.

*Significanceat ($p < .05$) requires $F(1,9) > 5.12$.

TABLE C_7

Behavioral practice 7 - The student develops ways of testing his proposed conclusions.

Null hypothesis C_7 - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 7 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	33.89	33.82	36.36	30.45	35.36
Group 2	No	31.53 38.35	33.00	33.13	34.88	31.64

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	33.976	33.753
Standard Deviation	2.240	2.560

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.1352	1	0.1352	0.0230
Within Groups	52.8401	9	5.8711	
Total	52.9753	10		

Not significant.

*Significance at ($p < .05$) requires $F\ (1,9) > 5.12$.

TABLE C_8

Behavioral practice 8 --The student constructs conceptual models.

Null hypothesis C_8 - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 8 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	33.89	34.88	30.45	31.64	35.36
Group 2	No	31.53 38.35	33.00	33.12	36.36	33.82

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	33.244	34.363
Standard Deviation	2.118	2.514

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	3.4170	1	3.4170	0.6205
Within Groups	49.5583	9	5.5065	
Total	52.9753	10		

Not significant.

*Significance at ($p < .05$) requires $F(1,9) > 5.12$.

TABLE C_9

<u>Behavioral practice 9</u> - The student criticizes his results.

<u>Null hypothesis C_9</u> - There is no significant difference in understanding of science, as measured by <u>TOUS</u>, between groups of students who exhibit the behavior specified in behavioral practice 9 and those groups of students who do not exhibit the behavior.

<u>Class Means</u>

Group 1	Yes	33.00	33.89	33.82	36.36	34.88
		30.45	35.36	38.35		
Group 2	No	31.53	33.12	31.64		

Treatment Group	1	2
Sample Size	8	3
Mean (Group)	34.514	32.097
Standard Deviation	2.350	0.888

<u>Analysis of Variance</u>

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	12.7468	1	12.7468	2.8517
Within Groups	40.2285	9	4.4698	
Total	52.9753	10		

Not significant.

*Significance at ($p < .05$) requires $F(1,9) > 5.12$.

TABLE C_{10}

Behavioral practice 10 - The student relates principles from one subject area to another.

Null hypothesis C_{10} - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 10 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	33.89	36.36	34.88	38.35	
Group 2	No	31.53 35.36	33.00	33.82	33.12	31.64

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	35.870	33.078
Standard Deviation	1.040	1.430

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	18.7042	1	18.7042	6.9529*
Within Groups	21.5211	8	2.6901	
Total	40.2252	9		

*Significant.

*Significance at ($p < .05$) requires $F(1,8) > 5.32$.

TABLE C_{11}

Behavioral practice 11 - The student selects the mathematical operations to be performed on quantitative information.

Null hypothesis C_{11} - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 11 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	33.89 35.36	33.82	36.36	30.45	31.64
Group 2	No	31.53	33.00	34.88	38.35	

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	33.587	34.440
Standard Deviation	2.219	2.945

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	1.7476	1	1.7476	0.2761
Within Groups	50.6341	8	6.3293	
Total	52.3818	9		

Not significant.

*Significance at ($p < .05$) requires $F\ (1,8) > 5.32$.

TABLE C_{12}

Behavioral practice 12 - The student writes an essay report.

Null hypothesis C_{12} - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 12 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	31.53	33.12	34.80	30.45	35.36
Group 2	No	33.00 38.35	33.89	33.82	36.36	31.64

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	33.068	34.510
Standard Deviation	2.107	2.431

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	5.6710	1	5.6710	1.0789
Within Groups	47.3043	9	5.2560	
Total	52.9753	10		

Not significant.

*Significance at ($p < .05$) requires $F(1,9) > 5.12$.

TABLE C_{13}

Behavioral practice 13 - The student observes and records accurately.

Null hypothesis C_{13} - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 13 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	33.00	33.87	33.82	36.36	34.88
		30.45	31.64	35.36	38.35	
Group 2	No	31.53	33.12			

Treatment Group	1	2
Sample Size	9	2
Mean (Group)	34.192	32.325
Standard Deviation	2.398	1.124

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	5.7052	1	5.7052	1.0863
Within Groups	47.2690	9	5.2521	
Total	52.9742	10		

Not significant.

*Significance at ($p < .05$) requires $F\ (1,9) > 5.12$.

TABLE C_{14}

Behavioral practice 14 - The student realizes the limitations of the instruments he is using.

Null hypothesis C_{14} - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 14 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	36.36	30.45	31.64	35.36	38.35
Group 2	No	31.53	33.00	33.82	34.88	

Treatment Group	1	2
Sample Size	5	4
Mean (Group)	34.432	33.308
Standard Deviation	3.301	1.413

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	2.8100	1	2.8100	0.3968
Within Groups	49.5702	7	7.0815	
Total	52.3802	8		

Not significant.

*Significance at ($p < .05$) requires $F(1,7) > 5.59$.

TABLE C_{15}

Behavioral practice 15 - The student re-evaluates his ideas and opinions.

Null hypothesis C_{15} - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 15 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	33.00	33.89	36.36	34.88	30.45
		35.36	38.35			
Group 2	No	33.82	31.64	33.12		

Treatment Group	1	2
Sample Size	7	3
Mean (Group)	34.613	32.860
Standard Deviation	2.520	1.113

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	6.4523	1	6.4523	1.2720
Within Groups	40.5791	8	5.0724	
Total	47.0314	9		

Not significant.

*Significance at ($p < .05$) requires $F(1,8) > 5.32$.

TABLE C_{16}

Behavioral practice 16 - The student suspends judgment on experimental outcomes until the data have been analyzed.

Null hypothesis C_{16} - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 16 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	31.53	33.89	33.82	36.36	34.88
		30.45	35.36			
Group 2	No	33.12	38.35			

Treatment Group	1	2
Sample Size	7	2
Mean (Group)	33.756	35.735
Standard Deviation	2.103	3.698

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	6.0940	1	6.0940	1.0611
Within Groups	40.2002	7	5.7429	
Total	46.2942	8		

Not significant.

*Significance at ($p < .05$) requires $F_{(1,7)} > 5.59$.

TABLE C_{17}

Behavioral practice 17 - The student suspends judgment on experimental outcomes until the data have been analyzed.

Null hypothesis C_{17} - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 17 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	33.82	30.45			
Group 2	No	31.53	33.00	33.89	33.12	36.36
		34.88	31.64	35.36	38.35	

Treatment Group	1	2
Sample Size	2	9
Mean (Group)	32.135	34.237
Standard Deviation	2.383	2.238

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	7.2278	1	7.2278	1.4219
Within Groups	45.7474	9	5.0830	
Total	52.9753	10		

Not significant.

*Significance at ($p < .05$) requires $F(1,9) > 5.12$.

TABLE C_{18}

Behavioral practice 18 - The students work on different laboratory problems at the same time.

Null hypothesis C_{18} - There is no significant difference in understanding of science, as measured by TOUS, between groups of students who exhibit the behavior specified in behavioral practice 18 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	33.89 38.35	33.82	36.36	30.45	35.36
Group 2	No	31.53	33.00	33.12	34.88	31.64

Treatment Group	1	2
Sample Size	6	5
Mean (Group)	34.705	32.834
Standard Deviation	2.684	1.362

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	9.5472	1	9.5472	1.9786
Within Groups	43.4281	9	4.8253	
Total	52.9753	10		

Not significant.

*Significance at ($p <.05$) requires $F\ (1,9) > 5.12$.

Summary for the Analysis of Scores on TOUS

As a result of the analysis of the data on TOUS, for behavioral practices 1 through 18, one practice was significant at the .05 level. Behavioral practice 10 favored the group that practiced the behavioral outcome which would indicate that student ability to relate principles from one subject area to another was extremely important for student understanding of science, as measured by TOUS. However, the investigator is also cognizant of the possibility that significance on this particular practice should be viewed with some scepticism. Since significance was not found on the other practices, it is possible that significant results on behavioral practice 10 may have been due to chance. It is interesting to note, however, that significance was found for the same behavioral practice in a parallel study which investigated behaviors exhibited by high school physics students.

The other practices all have highly nonsignificant F ratios, and the null hypothesis has been accepted in each case. In effect, analysis of the data indicated that there was no significant difference in understanding of science between groups regardless of whether they did or did not practice the following behaviors: (1) the student contributes to the procedure in solving a laboratory problem; (2) the student constructs graphs and interprets them; (3) the student analyzes and interprets data; (4) the student designs equipment; (5) the student establishes the limitations of the experimental conclusions; (6) the student uses unassigned reference material (excluding textbook); (7) the student develops ways of testing his proposed conclusions;

(8) the student constructs conceptual models; (9) the student criticizes his results; (11) the student selects the mathematical operations to be performed on quantitative information; (12) the student writes an essay report; (13) the student observes and records accurately; (14) the student realizes the limitations of the instrument he is using; (15) the student re-evaluates his ideas and opinions; (16) the student suspends judgment on experimental outcomes until the data have been analyzed; (17) the student proposes additional problems as a result of laboratory activities; and (18) the students work on different laboratory problems at the same time. Each of these factors as reported in this study and measured by TOUS did not contribute to student understanding of science.

The variability of TOUS is much less than that of VAS as reported in Table C. Thus more confidence can be placed in the reported scores on TOUS, and nonsignificant results in this study may be due to other factors such as length of observation or student motivation when taking the test. In addition, the teacher may not be striving for expressed student objectives in the classroom. The possibility is then raised that observed student behaviors may have been due to chance rather than teacher influence. The results also tend to indicate, with the exception of behavioral practice 10, that practices 1 through 18 did not contribute to a student's understanding of science in the classes that practiced these behaviors as well as those that did not.

TABLE D_1

Behavioral practice 1 - The student contributes to the procedure in solving a laboratory problem.

Null hypothesis D_1 - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 1 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.11	11.88	12.82	10.30	12.25
Group 2	No	10.70 14.04	11.54	12.76	12.69	11.84

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	11.672	12.262
Standard Deviation	0.987	1.160

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.9483	1	0.9483	0.8032
Within Groups	10.6252	9	1.1806	
Total	11.5735	10		

Not significant.

*Significance at ($p < .05$) requires $F (1,9) > 5.12$.

TABLE D_2

Behavioral practice 2 - The student constructs graphs and interprets them.

Null hypothesis D_2 - There is no significant difference in understanding of the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 2 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	10.73 11.84	11.11 12.25	11.88	12.82	10.30
Group 2	No	11.54	12.76	14.04		

Treatment Group	1	2
Sample Size	7	3
Mean (Group)	11.561	12.780
Standard Deviation	0.887	1.250

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	3.1183	1	3.1183	3.1783
Within Groups	7.8491	8	0.9811	
Total	10.9674	9		

Not significant.

*Significance at ($p < .05$) requires $F\ (1,8) > 5.32$.

TABLE D_3

Behavioral practice 3 - The student analyzes and interprets data.

Null hypothesis D_3 - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 3 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	10.75	11.54	11.11	11.88	12.82
		12.69	10.30	12.35	14.04	
Group 2	No	12.76	11.84			

Treatment Group	1	2
Sample Size	9	1
Mean (Group)	11.931	12.760
Standard Deviation	1.162	0.000

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.6184	1	0.6184	0.4580
Within Groups	10.8005	8	1.3501	
Total	11.4188	9		

Not significant.

*Significance at ($p < .05$) requires $F(1,8) > 5.32$.

TABLE D_4

Behavioral practice 4 - The student designs equipment.

Null hypothesis D_4 - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 4 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.88				
Group 2	No	10.73	11.54	11.11	12.76	12.82
		12.69	10.30	11.84	12.25	14.04

Treatment Group	1	2
Sample Size	1	10
Mean (Group)	11.880	12.008
Standard Deviation	0.000	1.129

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.0149	1	0.0149	0.0117
Within Groups	11.4818	9	1.2758	
Total	11.4967	10		

Not significant.

*Significance at ($p \leqslant .05$) requires $F(1,9) >$ 5.12.

TABLE D_5

Behavioral practice 5 - The student establishes the limitations of the experimental conclusions.

Null hypothesis D_5 - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 5 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.11	11.88	10.30		
Group 2	No	10.73	11.54	12.76	12.82	12.69
		12.25	14.04	11.84		

Treatment Group	1	2
Sample Size	3	8
Mean (Group)	11.097	12.334
Standard Deviation	0.790	0.993

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	3.3390	1	3.3390	3.6838
Within Groups	8.1577	9	0.9064	
Total	11.4967	10		

Not significant.

*Significance at ($p < .05$) requires $F\ (1,9) > 5.12$.

TABLE D_6

Behavioral practice 6 - The student uses unassigned reference material (excluding textbook).

Null hypothesis D_6 - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 6 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.88	12.82	10.30	12.25	14.04
Group 2	No	10.73 11.84	11.54	11.11	12.76	12.69

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	12.258	11.778
Standard Deviation	1.366	0.825

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.6275	1	0.6275	0.5196
Within Groups	10.8692	9	1.2077	
Total	11.4967	10		

Not significant.

*Significance at $(p < .05)$ requires $F(1,9) > 5.12$.

TABLE D_7

Behavioral practice 7 - The student develops ways of testing his proposed conclusions.

Null hypothesis D_7 - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 7 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.11	11.88	12.76	10.30	12.25
Group 2	No	10.73 14.04	11.54	12.76	12.69	11.84

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	11.660	12.267
Standard Deviation	0.969	1.152

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	1.0038	1	1.0038	0.8689
Within Groups	10.3973	9	1.1553	
Total	11.4011	10		

Not significant.

*Significance at ($p<.05$) requires $F(1,9)>5.12$.

TABLE D_8

Behavioral practice 8 - The student constructs conceptual models.

Null hyrothesis D_8 - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 8 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.11	12.69	10.30	11.84	12.25
Group 2	No	10.73 14.04	11.54	11.88	12.76	12.82

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	11.638	12.295
Standard Deviation	0.948	1.160

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	1.1772	1	1.1772	1.0267
Within Groups	10.3194	9	1.1466	
Total	11.4967	10		

Not significant.

*Significance at $(p<.05)$ requires $F(1,9)>5.12$.

TABLE D_9

Behavioral practice 9 - The student criticizes his results.

Null hypothesis D_9 - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 9 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.54	11.11	11.88	12.82	12.69
		10.30	12.25	14.04		
Group 2	No	10.73	12.76	11.84		

Treatment Group	1	2
Sample Size	8	3
Mean (Group)	12.079	11.777
Standard Deviation	1.148	1.016

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.1991	1	0.1991	0.1586
Within Groups	11.2976	9	1.2553	
Total	11.4967	10		

Not significant.

*Significance at ($p < .05$) requires $F(1,9) > 5.12$.

TABLE D_{10}

Behavioral practice 10 - The student relates principles from one subject area to another.

Null hypothesis D_{10} - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 10 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.11	12.82	12.69	14.04	
Group 2	No	10.73 12.25	11.54	11.88	12.76	11.84

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	12.665	11.833
Standard Deviation	1.202	0.684

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	1.6600	1	1.6600	1.9906
Within Groups	6.6712	8	0.8339	
Total	8.3312	9		

Not significant.

*Significance at ($p < .05$) requires $F(1,8) > 5.32$.

TABLE D_{11}

Behavioral practice 11 - The student selects the mathematical operations to be performed on quantitative information.

Null hypothesis D_{11} - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 11 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.11 12.25	11.88	12.82	10.30	11.84
Group 2	No	10.73	11.54	12.69	14.04	

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	11.700	12.250
Standard Deviation	0.885	1.439

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.7260	1	0.7260	0.5734
Within Groups	10.1292	8	1.2661	
Total	10.8552	9		

Not significant.

*Significance at $(p < .05)$ requires $F(1,8) > 5.32$.

TABLE D_{12}

Behavioral practice 12 - The student writes an essay report.

Null hypothesis D_{12} - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 12 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	10.73	12.76	12.69	10.30	12.25
Group 2	No	11.54 14.04	11.11	11.88	12.82	11.84

Treatment Group	1	2
Sample Size	5	6
Mean (Group)	11.746	12.205
Standard Deviation	1.151	1.061

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.5746	1	0.5746	0.4735
Within Groups	10.9221	9	1.2136	
Total	11.4967	10		

Not significant.

*Significance at ($p < .05$) requires $F(1,9) > 5.12$.

TABLE D_{13}

Behavioral practice 13 - The student observes and records accurately.

Null hypothesis D_{13} - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 13 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.54	11.11	11.88	12.82	12.69
		10.30	11.84	12.25	14.04	
Group 2	No	10.73	12.76			

Treatment Group	1	2
Sample Size	9	2
Mean (Group)	12.052	11.745
Standard Deviation	1.077	1.435

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.1544	1	0.1544	0.1226
Within Groups	11.3422	9	1.2602	
Total	11.4967	10		

Not significant.

*Significance at $(p<.05)$ requires $F\ (1,9)>5.12$.

TABLE D_{14}

Behavioral practice 14 - The student realizes the limitations of the instruments he is using.

Null hypothesis D_{14} - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 14 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	12.82	10.30	11.84	12.25	14.04
Group 2	No	10.73	11.54	11.88	12.69	

Treatment Group	1	2
Sample Size	5	4
Mean (Group)	12.250	11.710
Standard Deviation	1.369	0.812

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.6480	1	0.6480	0.4786
Within Groups	9.4782	7	1.3540	
Total	10.1262	8		

Not significant.

*Significance at ($p < .05$) requires F $(1,7) > 5.59$.

TABLE D_{15}

<u>Behavioral practice 15</u> - The student re-evaluates his ideas and opinions.

<u>Null hypothesis D_{15}</u> - There is no significant difference in understanding the methods and aims of science, as measured by Part III of <u>TOUS</u>, between groups of students who exhibit the behavior specified in behavioral practice 15 and those groups of students who do not exhibit the behavior.

<u>Class Means</u>

Group 1	Yes	11.54	11.11	12.82	12.69	10.30
		12.25	14.04.			
Group 2	No	11.88	12.76	11.84		

Treatment Group	1	2
Sample Size	7	3
Mean (Group)	12.107	12.160
Standard Deviation	1.237	0.520

<u>Analysis of Variance</u>

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.0059	1	0.0059	0.0048
Within Groups	9.7267	8	1.2158	
Total	9.7326	9		

Not significant.

*Significance at $(p < .05)$ requires $F\ (1,8) > 5.32$.

TABLE D_{16}

Behavioral practice 16 - The student suspends judgment on experimental outcomes until the data have been analyzed.

Null hypothesis D_{16} - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 16 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	10.73	11.11	11.88	12.82	12.69
		10.30	12.25			
Group 2	No	12.76	14.04			

Treatment Group	1	2
Sample Size	7	2
Mean (Group)	11.683	13.400
Standard Deviation	0.985	0.905

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	4.5867	1	4.5867	4.8386
Within Groups	6.6355	7	0.9479	
Total	11.2222	8		

Not significant.

*Significance at ($p<.05$) requires $F\ (1,7)>5.59$.

TABLE D_{17}

Behavioral practice 17 - The student proposes additional problems as a result of laboratory activities.

Null hypothesis D_{17} - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 17 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	11.88	10.30			
Group 2	No	10.73	11.54	11.11	12.76	12.82
		12.69	11.84	12.25	14.04	

Treatment Group	1	2
Sample Size	2	9
Mean (Group)	11.090	12.198
Standard Deviation	1.117	1.015

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	2.0081	1	2.0081	1.9047
Within Groups	9.4886	9	1.0543	
Total	11.4967	10		

Not significant.

*Significance at ($p < .05$) requires $F(1,9) > 5.12$.

TABLE D_{18}

Behavioral practice 18 - The students work on different laboratory problems at the same time.

Null hypothesis D_{18} - There is no significant difference in understanding the methods and aims of science, as measured by Part III of TOUS, between groups of students who exhibit the behavior specified in behavioral practice 18 and those groups of students who do not exhibit the behavior.

Class Means

Group 1	Yes	10.30 14.04	12.82	12.25	11.11	11.88
Group 2	No	10.73	11.54	12.69	12.76	11.84

Treatment Group	1	2
Sample Size	6	5
Mean (Group)	12.067	11.912
Standard Deviation	1.309	0.846

Analysis of Variance

	Sum of Squares	DF	Mean Square	F Ratio
Between Groups	0.0652	1	0.0652	0.0514
Within Groups	11.4314	9	1.2702	
Total	11.4967	10		

Not significant.

*Significance at ($p < .05$) requires $F(1,9) > 5.12$.

<u>Summary for the Analysis of Scores on Part III of TOUS</u>

As a result of the analysis of the data for behavioral practices 1 through 18 the null hypotheses were accepted. None are significant at the .05 level. This would tend to indicate that the behavioral practices did not contribute to a student's understanding of the methods and aims of science as determined by an analysis of class-sized groups. A trend does exist, however, in relation to behavioral practices 2, 5, and 16 which favors the group that did not practice each one of the following behavioral outcomes: the constructing of graphs and their interpretation; the establishing of the limitations of the experimental conclusions; and the suspension of judgment on experimental outcomes until the data have been analyzed. Since these three behavioral practices may have no effect upon a student's understanding of the methods and aims of science, further study is recommended to determine their significance for the chemistry student.

In contrast, no evidence was provided to indicate that the student performance of the following behavioral practices was important: (1) the student contributes to the procedure in solving a laboratory problem; (3) the student analyzes and interprets data; (4) the student designs equipment; (6) the student uses unassigned reference material (excluding textbook); (7) the student develops ways of testing his proposed conclusions; (8) the student constructs conceptual models; (9) the student criticizes his results; (10) the student relates principles from one subject area to another; (11) the student selects the mathematical operations to be performed on quantitative information;

(12) the student writes an essay report; (13) the student observes and records accurately; (14) the student realizes the limitations of the instrument he is using; (15) the student re-evaluates his ideas and opinions; (17) the student proposes additional problems as a result of laboratory activities; and (18) the students work on different laboratory problems at the same time.

The reliability of Part III of TOUS has been reported by the authors of the test as .58. An absence of results in this section may partially support the reported reliability coefficient for Part III of TOUS, and could possibly indicate the futility in using these subscores for group analysis purposes.

CHAPTER V

SUMMARY, CONCLUSIONS, RECOMMENDATIONS, AND IMPLICATIONS

Summary

In research studies involving the science laboratory in the high school science program it has been generally concluded that laboratory work is no more effective in increasing factual achievement than many other teaching procedures. However, the laboratory has been defended on the grounds that it augments student understanding of the more intangible objectives of science education. This statement may be correct, but little tangible evidence has been produced to indicate the extent to which these goals may or may not be achieved in the scientific laboratory. Yet, if the science laboratory is to remain as an essential part of the science program, it will be necessary to show that it makes important and essential contributions to the goals of science education. In this study an attempt has been made to determine the value of the scientific laboratory by delving into the less tangible areas of scientific attitudes, understanding of science, and understanding of the methods and aims of science.

The investigator and an associate developed a selected list of behavioral practices which, when practiced in the laboratory, might be related to an understanding of science, an understanding of the methods and aims of science, and an improved attitude toward science. The scientific literature, from 1900 to the present, was systematically surveyed for statements suggesting behavioral practices that might be related to an understanding of science, an understanding of the methods and aims of science, and an improved attitude toward science. Initially there were eighty-two statements obtained from approximately two hundred books and articles. Due to duplications, this list was reduced to forty-two behavioral practices exhibited by students and teachers. Only student behaviors were utilized in this study, rather than teacher behaviors, since student behaviors are more likely to be indicative of student beliefs, mores, and values.

The statements relating to student behaviors were written in behavioral terms. This resulted in a list of twenty-three student behaviors theorized by scientists and science educators to contribute to an understanding of science, an understanding of the methods and aims of science, and an improved attitude toward science. Following the elimination of those behaviors difficult to observe, a total of eighteen overt student behaviors comprised the observational instrument for this study.

Three categories were utilized in the evaluation of each of the behavioral practices included in the observational instrument. One category was "yes" (behavior was practiced by students in laboratory); the second was "no" (behavior was not practiced by students in laboratory); and the third was "unobserved" (behavior was not called for by the laboratory problem during period of observation). The number of students in each laboratory class exhibiting each behavioral practice was recorded on the evaluative instrument. A ratio was formed by comparing this number with the total number of students in the class which in turn was converted into a percentage. A quartile percentage was arbitrarily chosen for each behavioral practice, and, if the class percentage met or exceeded the predetermined percentage, it was checked as "yes".

The eleven high school chemistry classes that participated in this study had a total population of 276 students. The classes utilized in this study were located in Massachusetts and New Hampshire, and were chosen because it was the opinion of the investigator and his associate that they represented two ends of a continuum. One end of this continuum represented schools with chemistry classes in which students were encouraged to engage in many of the behavioral practices, while the other end of the continuum represented schools with chemistry classes in which the opposite was true. Initial contact of the schools involved in this study was based on the recommendations of a science educator, secondary school science teachers, and the investigator and his associate.

The observation of science laboratories and the testing of students were accomplished during the period from March to May, 1969. Using the behavioral practices in an observational instrument, the investigator and his associate noted overt student behavior in the laboratory. After the observational instrument had been utilized in the laboratory, two tests were administered. One was TOUS, and the second was VAS.

When the collection of data had been completed, each behavioral practice was then stated in a null hypothesis. The units of analysis for each of the behavioral practices listed in Appendix C were the mean average scores which the classes achieved on TOUS, VAS, and Part III of TOUS. The statistical technique utilized for the evaluation of the behavioral practices was a one-way analysis of variance F-test, and a statistically significant difference in the means resulted in the rejection of the null hypothesis. In turn, rejection of the null hypothesis would be interpreted as meaning that the particular observed laboratory behavior tested had contributed to either an understanding of science, as measured by TOUS, or an understanding of the methods and aims of science, as measured by Part III of TOUS, or an improved attitude toward science, as measured by VAS.

Conclusions

Results of Analysis on VAS.-- The interpretation of the results from the analysis of the attitude scale scores would seem to indicate that none of the following eighteen behavioral practices contributed to a better attitude toward science, as measured by VAS, for either those students practicing or not practicing these behaviors: (1) the student contributes to the procedure in solving a laboratory problem; (2) the student constructs graphs and interprets them; (3) the student analyzes and interprets data; (4) the student designs equipment; (5) the student establishes the limitations of the experimental conclusions; (6) the student uses unassigned reference material (excluding textbook); (7) the student develops ways of testing his proposed conclusions; (8) the student constructs conceptual models; (9) the student criticizes his results; (10) the student relates principles from one subject area to another; (11) the student selects the mathematical operations to be performed on quantitative information; (12) the student writes an essay report; (13) the student observes and records accurately; (14) the student realizes the limitations of the instrument he is using; (15) the student re-evaluates his ideas and opinions; (16) the student suspends judgment on experimental outcomes until the data have been analyzed; (17) the student proposes additional problems as a result of laboratory activities; (18) the students work on different laboratory problems at the same time.

While the F ratios of behavioral practices 4, 6, and 17 approached significance they were not large enough for the investigator to reject the respective null hypotheses. This would seem to indicate that further investigation is needed to determine the importance of the following behavioral practices in improving a student's attitude toward science: (4) the student designs equipment; (6) the student uses unassigned reference material (excluding textbook); (17) the student proposes additional problems as a result of laboratory activities.

Results of Analysis on TOUS.--The evidence obtained from the analysis of TOUS indicated the significance of one behavioral practice (Item 10) for an understanding of science. The significant difference favored the students who practiced the behavior. (The student relates principles from one subject area to another.) This finding was also obtained in a parallel study conducted in high school physics.

The remaining seventeen behavioral practices, as indicated by evidence from the analysis, are not significant for an understanding of science. Thus it would appear to be unimportant that students engage in the following practices if their understanding of science is to be increased: (1) the student contributes to the procedure in solving a laboratory problem; (2) the student constructs graphs and interprets them; (3) the student analyzes and interprets data; (4) the student designs equipment; (5) the student establishes the limitations of the experimental conclusions; (6) the student uses unassigned reference material (excluding textbook); (7) the student develops ways of testing his proposed conclusions; (8) the student constructs conceptual models; (9) the student criticizes his results; (11) the student selects the mathematical operations to be performed on quantitative information; (12) the student writes an essay report; (13) the student observes and records accurately; (14) the student realizes the limitations of the instrument he is using; (15) the student re-evaluates his ideas and opinions; (16) the student suspends judgment on experimental outcomes until the data have been analyzed; (17) the student proposes additional problems as a result of laboratory activities; and (18) the students work on different laboratory problems at the same time.

Results of Analysis on Part III of TOUS.-- Evidence obtained from the analysis of the test scores from Part III of TOUS would seem to indicate that none of the following eighteen behavioral practices contributes to a better understanding of the methods and aims of science for those students practicing or not practicing these behaviors: (1) the student contributes to the procedure in solving a laboratory problem; (2) the student constructs graphs and interprets them; (3) the student analyzes and interprets data; (4) the student designs equipment; (5) the student establishes the limitations of the experimental conclusions;

(6) the student uses unassigned reference material (excluding textbook); (7) the student develops ways of testing his proposed conclusions; (8) the student constructs conceptual models; (9) the student criticizes his results; (10) the student relates principles from one subject area to another; (11) the student selects the mathematical operations to be performed on quantitative information; (12) the student writes an essay report; (13) the student observes and records accurately; (14) the student realizes the limitations of the instrument he is using; (15) the student re-evaluates his ideas and opinions; (16) the student suspends judgment on experimental outcomes until the data have been analyzed; (17) the student proposes additional problems as a result of laboratory activities; (18) the students work on different laboratory problems at the same time.

The F ratios for behavioral practices 2, 5, and 16 were not significant, but were large enough to indicate that these three items need to be investigated further to assess the extent to which they promote an increased understanding of the methods and aims of science. The trend in F ratios favored those classes that did not practice the following behaviors: (2) the student constructs graphs and interprets them; (5) the student establishes the limitations of the experimental conclusions; (16) the student writes an essay report.

Recommendations

1. Studies are needed to investigate the type of interrelationship that exists between classroom activities and laboratory activities to determine the effect of one upon the other in promoting a student's

understanding of science, an understanding of the methods and aims of science, and an improved attitude toward science.

2. Investigations are needed which would study the effects that individual students have on the overt behaviors exhibited by their classmates. Class-generated enthusiasm or lack of enthusiasm for laboratory activities may depend upon the presence or absence of a certain type of student.

3. Studies are needed which would indicate whether certain student behaviors are elicited consistently by laboratory activities which have been judged to encourage these behavioral practices.

4. Future studies might attempt to determine those test items or groups of items that are directly related to the behavioral practices.

5. Further studies using different criterion measures should be completed, since TOUS and VAS may not be completely effective in measuring a student's understanding of science, understanding of the methods and aims of science, and improved attitude toward science. Moreover, TOUS and VAS may not be sensitive enough to measure small but significant changes that might be due to the effect of a student's practicing a single behavior.

6. An investigation should be conducted to determine the extent to which groups of varying ability profit from the scientific laboratory. Since chemistry is an elective course, the brighter students enroll in this subject. More studies are needed to determine if the same results are obtained for the average and below-average student enrolled in chemistry courses.

7. Since a limited number of students, encompassing a narrow geographical area, were involved in this study, additional studies need to be conducted using a larger sample population and a wider geographical area.

8. Since this study utilized only chemistry classes to investigate the effect of student laboratory behaviors on their understanding of science, understanding of the methods and aims of science, and improved attitude toward science, further studies utilizing other science courses should be initiated.

9. Studies are needed to investigate whether the objectives expressed by the teacher have been accepted by the students as the objectives.

Implications

The present study has identified a list of behavioral practices that should enhance the quality of the chemistry curriculum in relation to a student's understanding of science, understanding of the methods and aims of science, and improved attitude toward science. Although the analysis of the data produced no significant results, the investigator believes that this may be due to the following: (1) the observers may have noted student behaviors that were not representative of those displayed throughout the year; (2) students may have exhibited behaviors that were incidental to the desired goals of the teacher and student; (3) the student may not have realized that the teacher considered certain behaviors as being important; and (4) even if the student realized that certain laboratory behaviors were important, the teacher may not have evaluated the student on the basis of these behaviors.

In the statistical technique utilized in this study, independence was assumed for each of the behavioral practices, while the students' total test scores on TOUS, Part III of TOUS, and on VAS were used in computing the class means. This means that the total scores achieved by the students on the two criterion measures, TOUS and VAS, may not have been sensitive enough to measure the effect of a single behavioral practice. If this is the case, then specific evaluative techniques need to be developed to measure the effect of each behavioral practice, or an investigation should be conducted to determine whether certain items on TOUS and VAS may be more closely related to one behavioral practice than another.

In addition, an interrelationship may be present between groups of behavioral practices. If there is indeed such a relationship, the classes in which groups of highly correlated behaviors are practiced should be compared with those classes in which these groups of behaviors are not practiced. It might also be worthwhile to compare the classes where it was found that large numbers of students practiced the behaviors as opposed to those classes where few students practiced them. Thus, classes would be separated into two groups on the basis of whether or not students practiced or did not practice a certain number of behaviors. A score would be obtained for each class which would indicate its level of performance on the behavioral practices. This would provide a unitary measure showing the degree to which classes practiced the behaviors in the same way that a student's total test score on VAS and TOUS represents his understanding of science and improved attitude toward science.

The student learning process may not always be associated with readily observable student behaviors. This would indicate that it is entirely possible that students could have internalized certain behavioral practices without having displayed any overt behaviors. If this is the case, then evaluative instruments should be constructed that would elicit a student response which would be indicative of pupil understanding of the non-displayed behaviors. This type of evaluative instrument would provide a better assessment of whether or not students had learned and could use important behavioral practices.

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APPENDICES

APPENDIX A

SELECTED LIST OF ARTICLES USED IN FORMATION OF BEHAVIORAL PRACTICES

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APPENDIX B

BEHAVIORAL PRACTICES ELIMINATED AFTER TRIAL OBSERVATION IN HIGH SCHOOL SCIENCE LABORATORIES

1. The student is able to use a classification system.
2. The student develops generalizations from particulars.
3. The student demonstrates interest in the laboratory work.
4. Students work on different experiments at the same time.
5. The students contribute their own suggestions for operating the laboratory.

APPENDIX C

BEHAVIORAL PRACTICES

50% 1) The student contributes to the procedure in solving a laboratory problem.

Yes ____ No ____ Unobserved ____

75% 2) The student constructs graphs and interprets them.

Yes ____ No ____ Unobserved ____

50% 3) The student analyzes and interprets data.

Yes ____ No ____ Unobserved ____

25% 4) The student designs equipment.

Yes ____ No ____ Unobserved ____

50% 5) The student establishes the limitations of the experimental conclusions.

Yes ____ No ____ Unobserved ____

25% 6) The student uses unassigned reference material (excluding textbook).

Yes ____ No ____ Unobserved ____

25% 7) The student develops ways of testing his proposed conclusions.

Yes ____ No ____ Unobserved ____

25% 8) The student constructs conceptual models.

Yes ____ No ____ Unobserved ____

50% 9) The student criticizes his results.

Yes ____ No ____ Unobserved ____

25% 10) The student relates principles from one subject area to another.

Yes ____ No ____ Unobserved ____

75% 11) The student selects the mathematical operations to be performed on quantitative information.

Yes _____ No _____ Unobserved _____

75% 12) The student writes an essay report.

Yes _____ No _____ Unobserved _____

75% 13) The student observes and records accurately.

Yes _____ No _____ Unobserved _____

75% 14) The student realizes the limitations of the instrument he is using.

Yes _____ No _____ Unobserved _____

75% 15) The student re-evaluates his ideas and opinions.

Yes _____ No _____ Unobserved _____

75% 16) The student suspends final judgment on experimental outcomes until the data have been analyzed.

Yes _____ No _____ Unobserved _____

25% 17) The student proposes additional problems as a result of laboratory activities.

Yes _____ No _____ Unobserved _____

25% 18) The students work on different laboratory problems at the same time.

Yes _____ No _____ Unobserved _____

APPENDIX D

Class 1

1) The student contributes to the procedure in solving a laboratory problem.

Yes __X__ No _____ Unobserved _____

2) The student constructs graphs and interprets them.

Yes __X__ No _____ Unobserved _____

3) The student analyzes and interprets data.

Yes __X__ No _____ Unobserved _____

4) The student designs equipment.

Yes _____ No __X__ Unobserved _____

5) The student establishes the limitations of the experimental conclusions.

Yes __X__ No _____ Unobserved _____

6) The student uses unassigned reference material (excluding textbook).

Yes __X__ No _____ Unobserved _____

7) The student develops ways of testing his proposed conclusions.

Yes __X__ No _____ Unobserved _____

8) The student constructs conceptual models.

Yes __X__ No _____ Unobserved _____

9) The student criticizes his results.

Yes __X__ No _____ Unobserved _____

10) The student relates principles from one subject area to another.

Yes _____ No _____ Unobserved __X__

11) The student selects the mathematical operations to be performed on quantitative information.

Yes __X__ No _____ Unobserved _____

12) The student writes an essay report.

Yes __X__ No _____ Unobserved _____

13) The student observes and records accurately.

Yes __X__ No _____ Unobserved _____

14) The student realizes the limitations of the instrument he is using.

Yes __X__ No _____ Unobserved _____

15) The student re-evaluates his ideas and opinions.

Yes __X__ No _____ Unobserved _____

16) The student suspends final judgment on experimental outcomes until the data have been analyzed.

Yes __X__ No _____ Unobserved _____

17) The student proposes additional problems as a result of laboratory activities.

Yes __X__ No _____ Unobserved _____

18) The students work on different laboratory problems at the same time.

Yes __X__ No _____ Unobserved _____

APPENDIX D (continued)

Class 2

1) The student contributes to the procedure in solving a laboratory problem.

Yes __X__ No ____ Unobserved ____

2) The student constructs graphs and interprets them.

Yes __X__ No ____ Unobserved ____

3) The student analyzes and interprets data.

Yes __X__ No ____ Unobserved ____

4) The student designs equipment.

Yes ____ No __X__ Unobserved ____

5) The student establishes the limitations of the experimental conclusions.

Yes ____ No __X__ Unobserved ____

6) The student uses unassigned reference material (excluding textbook).

Yes __X__ No ____ Unobserved ____

7) The student develops ways of testing his proposed conclusions.

Yes __X__ No ____ Unobserved ____

8) The student constructs conceptual models.

Yes ____ No __X__ Unobserved ____

9) The student criticizes his results.

Yes __X__ No ____ Unobserved ____

10) The student relates principles from one subject area to another.

Yes __X__ No ____ Unobserved ____

11) The student selects the mathematical operations to be performed on quantitative information.

Yes __X__ No ____ Unobserved ____

12) The student writes an essay report.

Yes ____ No __X__ Unobserved ____

13) The student observes and records accurately.

Yes __X__ No ____ Unobserved ____

14) The student realizes the limitations of the instrument he is using.

Yes __X__ No ____ Unobserved ____

15) The student re-evaluates his ideas and opinions.

Yes __X__ No ____ Unobserved ____

16) The student suspends final judgment on experimental outcomes until the data have been analyzed.

Yes __X__ No ____ Unobserved ____

17) The student proposes additional problems as a result of laboratory activities.

Yes ____ No __X__ Unobserved ____

18) The students work on different laboratory problems at the same time.

Yes __X__ No ____ Unobserved ____

APPENDIX D (continued)

Class 3

1) The student contributes to the procedure in solving a laboratory problem.

Yes ____ No _X_ Unobserved ____

2) The student constructs graphs and interprets them.

Yes _X_ No ____ Unobserved ____

3) The student analyzes and interprets data.

Yes _X_ No ____ Unobserved ____

4) The student designs equipment.

Yes ____ No _X_ Unobserved ____

5) The student establishes the limitations of the experimental conclusions.

Yes ____ No _X_ Unobserved ____

6) The student uses unassigned reference material (excluding textbook).

Yes ____ No _X_ Unobserved ____

7) The student develops ways of testing his proposed conclusions.

Yes ____ No _X_ Unobserved ____

8) The student constructs conceptual models.

Yes ____ No _X_ Unobserved ____

9) The student criticizes his results.

Yes ____ No _X_ Unobserved ____

10) The student relates principles from one subject area to another.

Yes ____ No _X_ Unobserved ____

11) The student selects the mathematical operations to be performed on quantitative information.

Yes ____ No _X_ Unobserved ____

12) The student writes an essay report.

Yes __X__ No _____ Unobserved _____

13) The student observes and records accurately.

Yes _____ No __X__ Unobserved _____

14) The student realizes the limitations of the instrument he is using.

Yes _____ No __X__ Unobserved _____

15) The student re-evaluates his ideas and opinions.

Yes _____ No _____ Unobserved __X__

16) The student suspends final judgment on experimental outcomes until the data have been analyzed.

Yes __X__ No _____ Unobserved _____

17) The student proposes additional problems as a result of laboratory activities.

Yes _____ No __X__ Unobserved _____

18) The students work on different laboratory problems at the same time.

Yes _____ No __X__ Unobserved _____

APPENDIX D (continued)

Class 4

1) The student contributes to the procedure in solving a laboratory problem.

Yes __X__ No _____ Unobserved _____

2) The student constructs graphs and interprets them.

Yes __X__ No _____ Unobserved _____

3) The student analyzes and interprets data.

Yes __X__ No _____ Unobserved _____

4) The student designs equipment.

Yes _____ No __X__ Unobserved _____

5) The student establishes the limitations of the experimental conclusions.

Yes _____ No __X__ Unobserved _____

6) The student uses unassigned reference material (excluding textbook).

Yes __X__ No _____ Unobserved _____

7) The student develops ways of testing his proposed conclusions.

Yes __X__ No _____ Unobserved _____

8) The student constructs conceptual models.

Yes __X__ No _____ Unobserved _____

9) The student criticizes his results.

Yes __X__ No _____ Unobserved _____

10) The student relates principles from one subject area to another.

Yes _____ No __X__ Unobserved _____

11) The student selects the mathematical operations to be performed on quantitative information.

Yes __X__ No _____ Unobserved _____

12) The student writes an essay report.

Yes __X__ No _____ Unobserved _____

13) The student observes and records accurately.

Yes __X__ No _____ Unobserved _____

14) The student realizes the limitations of the instrument he is using.

Yes __X__ No _____ Unobserved _____

15) The student re-evaluates his ideas and opinions.

Yes __X__ No _____ Unobserved _____

16) The student suspends final judgment on experimental outcomes until the data have been analyzed.

Yes __X__ No _____ Unobserved _____

17) The student proposes additional problems as a result of laboratory activities.

Yes _____ No __X__ Unobserved _____

18) The students work on different laboratory problems at the same time.

Yes __X__ No _____ Unobserved _____

APPENDIX D (continued)

Class 5

1) The student contributes to the procedure in solving a laboratory problem.

Yes ____ No __X__ Unobserved ____

2) The student constructs graphs and interprets them.

Yes ____ No ____ Unobserved __X__

3) The student analyzes and interprets data.

Yes __X__ No ____ Unobserved ____

4) The student designs equipment.

Yes ____ No __X__ Unobserved ____

5) The student establishes the limitations of the experimental conclusions.

Yes ____ No __X__ Unobserved ____

6) The student uses unassigned reference material (excluding testbook).

Yes ____ No __X__ Unobserved ____

7) The student develops ways of testing his proposed conclusions.

Yes ____ No __X__ Unobserved ____

8) The student constructs conceptual models.

Yes __X__ No ____ Unobserved ____

9) The student criticizes his results.

Yes __X__ No ____ Unobserved ____

10) The student relates principles from one subject area to another.

Yes __X__ No ____ Unobserved ____

11) The student selects the mathematical operations to be performed on quantitative information.

Yes ____ No __X__ Unobserved ____

12) The student writes an essay report.

Yes __X__ No _____ Unobserved _____

13) The student observes and records accurately.

Yes __X__ No _____ Unobserved _____

14) The student realizes the limitations of the instrument he is using.

Yes _____ No __X__ Unobserved _____

15) The student re-evaluates his ideas and opinions.

Yes __X__ No _____ Unobserved _____

16) The student suspends final judgment on experimental outcomes until the data have been analyzed.

Yes __X__ No _____ Unobserved _____

17) The student proposes additional problems as a result of laboratory activities.

Yes _____ No __X__ Unobserved _____

18) The students work on different laboratory problems at the same time.

Yes _____ No __X__ Unobserved _____

APPENDIX D (continued)

Class 6

1) The student contributes to the procedure in solving a laboratory problem.

Yes ____ No __X__ Unobserved ____

2) The student constructs graphs and interprets them.

Yes __X__ No ____ Unobserved ____

3) The student analyzes and interprets data.

Yes ____ No __X__ Unobserved ____

4) The student designs equipment.

Yes ____ No __X__ Unobserved ____

5) The student establishes the limitations of the experimental conclusions.

Yes ____ No __X__ Unobserved ____

6) The student uses unassigned reference material (excluding textbook).

Yes ____ No __X__ Unobserved ____

7) The student develops ways of testing his proposed conclusions.

Yes ____ No __X__ Unobserved ____

8) The student constructs conceptual models.

Yes __X__ No ____ Unobserved ____

9) The student criticizes his results.

Yes ____ No __X__ Unobserved ____

10) The student relates principles from one subject area to another.

Yes ____ No __X__ Unobserved ____

11) The student selects the mathematical operations to be performed on quantitative information.

Yes __X__ No ____ Unobserved ____

12) The student writes an essay report.

Yes ____ No __X__ Unobserved ____

13) The student observes and records accurately.

Yes __X__ No ____ Unobserved ____

14) The student realizes the limitations of the instrument he is using.

Yes __X__ No ____ Unobserved ____

15) The student re-evaluates his ideas and opinions.

Yes ____ No __X__ Unobserved ____

16) The student suspends final judgment on experimental outcomes until the data have been analyzed.

Yes ____ No ____ Unobserved __X__

17) The student proposes additional problems as a result of laboratory activities.

Yes ____ No __X__ Unobserved ____

18) The students work on different laboratory problems at the same time.

Yes ____ No __X__ Unobserved ____

APPENDIX D (continued)

Class 7

1) The student contributes to the procedure in solving a laboratory problem.

Yes ____ No __X__ Unobserved ____

2) The student constructs graphs and interprets them.

Yes ____ No __X__ Unobserved ____

3) The student analyzes and interprets data.

Yes __X__ No ____ Unobserved ____

4) The student designs equipment.

Yes ____ No __X__ Unobserved ____

5) The student establishes the limitations of the experimental conclusions.

Yes ____ No __X__ Unobserved ____

6) The student uses unassigned reference material (excluding textbook).

Yes __X__ No ____ Unobserved ____

7) The student develops ways of testing his proposed conclusions.

Yes ____ No __X__ Unobserved ____

8) The student constructs conceptual models.

Yes ____ No __X__ Unobserved ____

9) The student criticizes his results.

Yes __X__ No ____ Unobserved ____

10) The student relates principles from one subject area to another.

Yes __X__ No ____ Unobserved ____

11) The student selects the mathematical operations to be performed on quantitative information.

Yes ____ No __X__ Unobserved ____

12) The student writes an essay report.

Yes ____ No __X__ Unobserved ____

13) The student observes and records accurately.

Yes __X__ No ____ Unobserved ____

14) The student realizes the limitations of the instrument he is using.

Yes __X__ No ____ Unobserved ____

15) The student re-evaluates his ideas and opinions.

Yes __X__ No ____ Unobserved ____

16) The student suspends final judgment on experimental outcomes until the data have been analyzed.

Yes ____ No __X__ Unobserved

17) The student proposes additional problems as a result of laboratory activities.

Yes ____ No __X__ Unobserved ____

18) The students work on different laboratory problems at the same time.

Yes __X__ No ____ Unobserved ____

APPENDIX D (continued)

Class 8

1) The student contributes to the procedure in solving a laboratory problem.

Yes __X__ No _____ Unobserved _____

2) The student constructs graphs and interprets them.

Yes __X__ No _____ Unobserved _____

3) The student analyzes and interprets data.

Yes __X__ No _____ Unobserved _____

4) The student designs equipment.

Yes _____ No __X__ Unobserved _____

5) The student establishes the limitations of the experimental conclusions.

Yes __X__ No _____ Unobserved _____

6) The student uses unassigned reference material (excluding textbook).

Yes _____ No __X__ Unobserved _____

7) The student develops ways of testing his proposed conclusions.

Yes __X__ No _____ Unobserved _____

8) The student constructs conceptual models.

Yes __X__ No _____ Unobserved _____

9) The student criticizes his results.

Yes __X__ No _____ Unobserved _____

10) The student relates principles from one subject area to another.

Yes __X__ No _____ Unobserved _____

11) The student selects the mathematical operations to be performed on quantitative information.

Yes __X__ No _____ Unobserved _____

12) The student writes an essay report.

Yes ____ No _X_ Unobserved ____

13) The student observes and records accurately.

Yes _X_ No ____ Unobserved ____

14) The student realizes the limitations of the instrument he is using.

Yes ____ No ____ Unobserved _X_

15) The student re-evaluates his ideas and opinions.

Yes _X_ No ____ Unobserved ____

16) The student suspends final judgment on experimental outcomes until the data have been analyzed.

Yes _X_ No ____ Unobserved ____

17) The student proposes additional problems as a result of laboratory activities.

Yes ____ No _X_ Unobserved ____

18) The students work on different laboratory problems at the same time.

Yes _X_ No ____ Unobserved ____

APPENDIX D (continued)

Class 9

1) The student contributes to the procedure in solving a laboratory problem.

Yes ____ No _X_ Unobserved ____

2) The student constructs graphs and interprets them.

Yes ____ No _X_ Unobserved ____

3) The student analyzes and interprets data.

Yes ____ No _X_ Unobserved ____

4) The student designs equipment.

Yes ____ No _X_ Unobserved ____

5) The student establishes the limitations of the experimental conclusions.

Yes ____ No _X_ Unobserved ____

6) The student uses unassigned reference material (excluding textbook).

Yes ____ No _X_ Unobserved ____

7) The student develops ways of testing his proposed conclusions.

Yes ____ No _X_ Unobserved ____

8) The student constructs conceptual models.

Yes ____ No _X_ Unobserved ____

9) The student criticizes his results.

Yes ____ No _X_ Unobserved ____

10) The student relates principles from one subject area to another.

Yes ____ No _X_ Unobserved ____

11) The student selects the mathematical operations to be performed on quantitative information.

Yes ____ No ____ Unobserved _X_

12) The student writes an essay report.

Yes __X__ No _____ Unobserved _____

13) The student observes and records accurately.

Yes _____ No __X__ Unobserved _____

14) The student realizes the limitations of the instrument he is using.

Yes _____ No _____ Unobserved __X__

15) The student re-evaluates his ideas and opinions.

Yes _____ No __X__ Unobserved _____

16) The student suspends final judgment on experimental outcomes until the data have been analyzed.

Yes _____ No __X__ Unobserved _____

17) The student proposes additional problems as a result of laboratory activities.

Yes _____ No __X__ Unobserved _____

18) The students work on different laboratory problems at the same time.

Yes _____ No __X__ Unobserved _____

APPENDIX D (continued)

Class 10

1) The student contributes to the procedure in solving a laboratory problem.

Yes _X_ No ___ Unobserved ___

2) The student constructs graphs and interprets them.

Yes _X_ No ___ Unobserved ___

3) The student analyzes and interprets data.

Yes _X_ No ___ Unobserved ___

4) The student designs equipment.

Yes _X_ No ___ Unobserved ___

5) The student establishes the limitations of the experimental conclusions.

Yes _X_ No ___ Unobserved ___

6) The student uses unassigned reference material (excluding textbook).

Yes _X_ No ___ Unobserved ___

7) The student develops ways of testing his proposed conclusions.

Yes _X_ No ___ Unobserved ___

8) The student constructs conceptual models.

Yes ___ No _X_ Unobserved ___

9) The student criticizes his results.

Yes _X_ No ___ Unobserved ___

10) The student relates principles from one subject area to another.

Yes ___ No _X_ Unobserved ___

11) The student selects the mathematical operations to be performed on quantitative information.

Yes _X_ No ___ Unobserved ___

12) The student writes an essay report.

Yes ____ No _X_ Unobserved ____

13) The student observes and records accurately.

Yes _X_ No ____ Unobserved ____

14) The student realizes the limitations of the instrument he is using.

Yes ____ No _X_ Unobserved ____

15) The student re-evaluates his ideas and opinions.

Yes ____ No _X_ Unobserved ____

16) The student suspends final judgment on experimental outcomes until the data have been analyzed.

Yes _X_ No ____ Unobserved ____

17) The student proposes additional problems as a result of laboratory activities.

Yes _X_ No ____ Unobserved ____

18) The students work on different laboratory problems at the same time.

Yes _X_ No ____ Unobserved ____

APPENDIX D (continued)

Class 11

1) The student contributes to the procedure in solving a laboratory problem.

Yes ____ No _X_ Unobserved ____

2) The student constructs graphs and interprets them.

Yes ____ No _X_ Unobserved ____

3) The student analyzes and interprets data.

Yes _X_ No ____ Unobserved ____

4) The student designs equipment.

Yes ____ No _X_ Unobserved ____

5) The student establishes the limitations of the experimental conclusions.

Yes ____ No _X_ Unobserved ____

6) The student uses unassigned reference material (excluding textbook).

Yes ____ No _X_ Unobserved ____

7) The student develops ways of testing his proposed conclusions.

Yes ____ No _X_ Unobserved ____

8) The student constructs conceptual models.

Yes ____ No _X_ Unobserved ____

9) The student criticizes his results.

Yes _X_ No ____ Unobserved ____

10) The student relates principles from one subject area to another.

Yes ____ No _X_ Unobserved ____

11) The student selects the mathematical operations to be performed on quantitative information.

Yes ____ No _X_ Unobserved ____

12) The student writes an essay report.

Yes ____ No __X__ Unobserved ____

13) The student observes and records accurately.

Yes __X__ No ____ Unobserved ____

14) The student realizes the limitations of the instrument he is using.

Yes ____ No __X__ Unobserved ____

15) The student re-evaluates his ideas and opinions.

Yes __X__ No ____ Unobserved ____

16) The student suspends final judgment on experimental outcomes until the data have been analyzed.

Yes ____ No ____ Unobserved __X__

17) The student proposes additional problems as a result of laboratory activities.

Yes ____ No __X__ Unobserved ____

18) The students work on different laboratory problems at the same time.

Yes ____ No __X__ Unobserved ____

APPENDIX E

PHYSICAL CHARACTERISTICS OF SCHOOLS AND COMMUNITIES

School	School Enrollment	Grade Levels	Number of Chemistry Sections	Number of Chemistry Students in Class Tested	Population of Community	Description of Community
1	1000	7-12	3	40	7000	Regional School, rural
2	900	7-12	6	39	8200	Regional School, college community
3	1000	9-12	5	30	15,000	College Community
4	2800	9-12	10	28	39,000	Upper Class, suburban community
5	1250	9-12	9	26	20,000	Regional School, middle class
6	1200	10-12	7	25	52,000	Factory Community, two parochial schools
7	500	9-12	2	23	7400	Industrial Community, isolated
8	605	7-12	2	18	7000	Regional School, rural
9	350	9-12	3	17	2100	Regional School, rural
10	1100	7-12	4	17	5500	Regional School, rural
11	550	7-12	2	13	6000	Community School, rural

APPENDIX F

DESCRIPTION OF CLASSES

Class No. 1: An atmosphere of freedom prevailed in the laboratory in which students spent nearly all of their laboratory time working with problem-solving activities. The teacher provided little direction for the students, but acted as a consultant with whom students discussed their questions. Often the teacher motivated his students by asking them questions to help clarify their own thinking rather than giving direct answers to questions the students posed. The laboratory was well-equipped with many reference books on display. The students were well-disciplined and took a keen interest in their work. Enthusiasm on the part of the students was evident, and, at the same time, they were allowed to participate in choosing the laboratory experiments to be performed. The pupils did not seem to take advantage of the freedom given to them.

Class No. 2: The contract method was used in this laboratory setting as well as in the regular classroom. Students, working on different experiments at the same time, agreed to complete a certain amount of laboratory work for each unit of material in order to obtain a specific grade. Each student was free to arrive and leave at will with little teacher direction. Thus, the student set up his own schedule of laboratory periods. Discipline was not a major concern of the instructor, but he often entered into group discussion concerning laboratory problems. Laboratory equipment was abundant with ample room for the performance of experiments.

Class No. 3: Laboratory classes met for two class periods each week. The environment of the laboratory seemed highly contrived. That is, everything was set up for the students prior to their arrival. Students were then directed to conduct experiments in a specific fashion, and were informed of the expected outcomes. This appeared to limit student-teacher conversations, and it was rare that a student even approached the teacher. Although there was sufficient equipment, added space in which to perform experiments seemed necessary.

Class No. 4: The students spent nearly 40 per cent of their total time in the laboratory. Working in groups the students were presented with a problem. Experimental procedures for attacking the problem were often developed by the students. In addition, students were encouraged to explain the phenomena they observed in the laboratory and to analyze the results of experiments. Students frequently discussed problems among themselves and with the teacher. The teacher hesitated giving direct answers to students' questions, but asked questions of his own to help the student organize his thinking. Actually, however, a lack of maturity seemed evident among the students who were unable to effectively use the freedom of the classroom.

Class No. 5: Laboratory sessions were held at least twice a week. In a classroom with adequate equipment and lab benches in the back, pre-laboratory classes were frequently conducted in which students were often given a demonstration to introduce the laboratory work. The use of the scientific method and the construction of models were emphasized throughout the course of the laboratory. The teacher encouraged student discussion, and a high degree of interest as well as good discipline were characteristic of the classroom atmosphere. There seemed to be a sense of purpose in this laboratory.

Class No. 6: Laboratory sessions were convened about once a week. The students were given exact directions, and were not encouraged to develop ideas on their own. There was strict adherence to the prescribed textbook, as well as to a standard laboratory manual. The students were quiet, and the teacher was in complete control. Ample equipment was available for the students.

Class No. 7: This class typified the traditional type laboratory in which the instructor often lectures to the students and in which the laboratory manual is followed very closely. Students met in the laboratory at least once a week to verify information presented in the classroom. The teacher directly answered the students' questions, and gave short lectures. The students were expected to repeat experiments until they were completed satisfactorily.

Class No. 8: Laboratory classes were held on an average of four times each week. The science room was not very well-equipped. On the other hand, good rapport was maintained between the student and teacher. A pre-laboratory session was conducted where the teacher aroused the curiosity of the students by presenting the problem to be considered in the laboratory that day. The teacher displayed a great deal of understanding toward his students and won their respect. He preferred to lead them to the answers they sought rather than state them directly. The students were also encouraged to present their own explanations of the phenomena that they observed in the laboratory. This also seemed to enhance the student-teacher rapport.

Class No. 9: Students spent about 30 per cent of their time in a laboratory which was not very well-equipped. In addition, the teacher, who lacked a good background in science, was very anxious to provide students with the information they requested. Explanations and direct answers were provided by the teacher, and the textbook was closely followed. The instructor was, however, interested in the enquiry approach although he did not make full use of this method during the period of observation. Fairly good discipline was maintained in the laboratory by the teacher.

Class No. 10: Laboratory sessions usually occurred twice during the week. Students were encouraged by the teacher to consider experimental procedures carefully. One indication of the students' interest was evidenced in their repetition of experiments where outcomes were unsatisfactory. The free environment was characterized by music that the students provided for themselves. The teacher believed in the importance of the problem-solving method, and individual students varied the procedure used in solving the same problem.

Class No. 11: In the laboratory, which comprised 30 per cent of the students' chemistry instruction, all of the materials for performing the experiments were provided by the teacher. Equipment was adequate but not plentiful. The directions in the laboratory manual were rigidly followed, and direct answers were given to the students' questions. The teacher seemed nervous and inexperienced. The students were not highly motivated, and discipline was just average.

CHEMISTRY LABORATORY BEHAVIORS AFFECTING

SCIENTIFIC UNDERSTANDING AND

ATTITUDE DEVELOPMENT

Mark Fernald Waltz

Chairman: Dr. Leverne John Thelen

Purposes of the Study

The purposes of this study were: (1) to delineate a list of behavioral practices related to an understanding of science, an understanding of the methods and aims of science, and an improved attitude toward science, as recommended by science educators that students should perform in the chemistry laboratory; and (2) to determine which of these behavioral practices contribute most to an understanding of science, an understanding of the methods and aims of science, and an improved scientific attitude, as measured by the Test on Understanding Science (TOUS), and the Vitrogan Attitude Scale (VAS).

Procedure

The scientific literature from 1900 to the present was reviewed in order to determine those behavioral practices associated with student laboratory behaviors that might be related to an understanding of science, an understanding of the methods and aims of science, and an improved attitude toward science. For evaluative purposes the initial list of eighty-two statements was subsequently reduced to a total of eighteen behavioral practices.

Overt behavior of students in eleven high school chemistry classes was observed in an attempt to determine the extent to which the students engaged in the behavioral practices. The classes were chosen because, in the judgment of the investigator and an associate, these classes represented two ends of a continuum. One end of this continuum represented schools with chemistry classes in which it was judged that students were encouraged to engage in many of the behavioral practices, while the other end of the continuum represented schools with chemistry classes in which it was judged that the opposite was true.

Observations of students in science laboratories and the testing of students were accomplished during the period from March to May, 1969. Using the behavioral practices in an observational instrument, the investigator and his associate noted overt student behavior in the laboratory. The number of students in each laboratory class exhibiting each behavioral practice was recorded on the evaluative instrument. A ratio was formed by comparing this number with the total number of students in the class which in turn was converted into a percentage. This class percentage was compared with an arbitrarily chosen quartile percentage to determine if it met or exceeded the quartile percentage. After the observational instrument had been utilized in the laboratory, two tests were administered, namely TOUS and VAS.

When the collection of data had been completed, each behavioral practice was then stated in a null hypothesis. The units of analysis for each of the behavioral practices were the mean average scores which the classes achieved on TOUS, VAS, and Part III of TOUS. The statistical technique was a one-way analysis of variance F-test.

Findings

1. The results from the analysis of the attitude scale scores indicated that none of the eighteen behavioral practices investigated contributed to a better attitude toward science, as measured by VAS, for either those students practicing or not practicing these behaviors.

2. The evidence obtained from the analysis of TOUS indicated the significance of one behavioral practice in favor of the classes in which students practiced the behavior of relating principles from one subject area to another. On the basis of these findings, it could then be concluded that a better understanding of science is achieved if pupils understand the relationships that exist across disciplines. The remaining seventeen behavioral practices, on the basis of the analysis, were not significant in promoting an increased understanding of science.

3. Evidence obtained from the analysis of the test scores from Part III of TOUS indicated that none of the listed eighteen behavioral practices contributed to a better understanding of the methods and aims of science.